Materials
in Design Engineering

Formerly Materials & Methods

MATERIALS SELECTOR

1957-58 REFERENCE ISSUE

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Data Section
Directory Section

Metals • Nonmetallics • Forms • Finishes

How to Use the MATERIALS SELECTOR

■ This Materials Selector issue consists of two major sections. a Data Section and a Directory Section. Each major section is subdivided to make it as useful as possible. Contents of the entire issue are listed on page 3; in addition, a more detailed contents page appears at the beginning of most subsections All subsections, numbered from 1 to 10, are described briefly below and can be readily located by means of the small edge index tabs.

DATA SECTION

The Data Section consists of eight parts, including an index. It contains extensive data on the properties of virtually all important engineering materials (including finishes and coatings) and the forms in which they are available.

1—Index to Data. A complete cross referenced index to all of the materials and forms covered in the Data Section.

2—Comparisons of Materials. Tables comparing the important engineering materials with respect to a particular property (e.g., tensile strength). The major part of this section is a series of data sheets in which materials are ranked in descending order for various properties. In most cases, the materials are ranked by their average properties, the approximate range also being given. In some cases the temper, heat treatment or other condition of the material is given, particularly where such condition markedly affects the value. More details on materials and conditions can be found in Sections 3 to 6, from which these data were compiled.

3 to 7—Properties of Materials. Typical properties and uses of the important engineering materials. The five sections cover Irons and Steels (3), Nonferrous Metals (4), Plastics and Rubber (5), Other Nonmetallics (6), and Finishes and Coatings (7). Most of the information is given in a standard tabular form, making comparison easy, and test conditions are summarized where known. A list of helpful bulletins available from suppliers appears at the beginning of each section, and advertisements of suppliers appear at the end of each section.

8—Forms and Shapes of Materials. Data on the common forms (castings, moldings, etc.) of engineering materials necessary for intelligent selection. Much of the information is in tabular form. A list of helpful bulletins available from suppliers appears at the beginning of the section, and advertisements of suppliers appear at the end of the section.

DIRECTORY SECTION

The Directory Section, consisting of two parts, contains the names of the leading suppliers of engineering materials and their forms and shapes. A full explanation of the organization and use of the Directory is given on page 366.

9—Suppliers of Materials. An alphabetical index to the important engineering materials and fabricated forms containing, under each heading, the names of the leading suppliers.

10—Addresses of Suppliers. An alphabetical list of the names and addresses of the suppliers mentioned in Section 9.

continued

SELECTING A MATERIAL

Naturally, you can use this issue in many different ways, depending upon the nature of your own materials problems. However, this issue is called the Materials Selector because it is designed to help you systematically narrow your choice of materials to meet a specific problem. Here is a logical procedure:

1. See Section 2 (Comparisons of Materials). Look up the critical properties and see which materials seem to warrant further investigation.

2. See Section 1 (Index to Data). Find what pages give information on the materials selected for study.

3. See Sections 3, 4, 5, 6 or 7 (Properties of Materials). Look up the pages indicated by the Index. Reduce the number of materials requiring further study by comparing significant properties, available forms and typical uses.

4. See Section 8 (Forms and Shapes of Materials). Narrow the choice of materials further by comparing the characteristics of competitive forms and shapes.

5. See Section 9 (Suppliers of Materials). Look up still promising materials and forms to obtain the names of suppliers, as well as a good indication of commercial availability.

6. See Section 10 (Addresses of Suppliers). Look up the names of promising suppliers to obtain their addresses.

7. Obtain detailed information on properties, availability and cost of materials and fabricated forms by:

a. Writing to suppliers.

b. Consulting the Suppliers' Literature pages in Sections 3, 4, 5, 6, 7 and 8. Note the key numbers of promising bulletins and circle them on the free post card (pp 363 and 421).

c. Consulting the advertisements. Names of advertisers are bold faced throughout the Directory, and the pages on which their advertisements appear are listed following their addresses.

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MATERIALS SELECTOR

1957-58 REFERENCE ISSUE

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DATA
SECTION

Comparisons of Materials

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Specific Gravity

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Osmium	22.7	—	Polystyrenes, GP	1.55	0.02
Iridium	22.5	—	Plastics Laminates, GP	1.52	0.38
Platinum	21.5	—	Bast Fiber	1.51	0.04
Tungsten and Gold	19.4	—	Diallyl Phthalate	1.5	0.2
Tantalum	16.6	—	Melamines, Fabric-Filled	1.5	—
Hafnium	13	—	Ureas	1.49	0.03
Rhodium	12.4	—	Melamines, Unfilled	1.48	—
Palladium and Ruthenium	12	—	Animal Fiber	1.45	0.15
Thorium	11.6	—	Rubber Phenolics	1.44	0.21
Lead and Its Alloys	11.0	0.3	Phenolics, GP	1.43	0.12
Silver	10.5	—	Plastics Laminates, Elec & Mech	1.41	0.27
Lead-Base Babbitts	9.96	0.66	Cellulose Nitrate Sheet	1.37	0.03
Copper	8.92	0.03	Hard Rubber, GP	1.37	0.17
Cobalt	8.92	—	Polyvinyl Chloride	1.35	0.20
Nickel	8.9	—	Polysulfide Rubber	1.35	—
Nickel Silvers (cast)	8.86	—	Polystyrenes and Nylons, Glass Fiber-Filled	1.33	0.02
Phosphor Bronzes	8.85	0.07	Phenolics (cast)	1.32	0.01
Nickel Silvers	8.71	0.04	Cellulose Acetate	1.30	0.04
Monel	8.66	0.18	Polyesters (cast), Rigid	1.29	0.17
Plain Brasses	8.62	0.23	Polyvinyl Alcohol	1.26	0.05
Columbium	8.6	—	Neoprene, Silicone and Urethane Rubbers	1.25	—
Monel (cast)	8.50	0.14	Hard Rubber, Cml Res	1.24	—
Tin and Aluminum Brasses	8.43	0.09	Cellulose Propionate	1.21	0.03
Inconel	8.34	0.09	Cellulose Acetate Butyrate	1.20	0.05
Nickel (cast)	8.34	—	Polysulfide-Epoxy (cast)	1.19	0.04
Duranickel	8.26	—	Borosilicate Glass	1.18	0.95
Beryllium Coppers	8.22	0.03	Acrylics	1.18	0.01
Inconel (cast)	8.20	0.12	Epoxies (cast)	1.17	0.02
Low Expansion Nickel Alloys	8.14	0.06	Polyesters (cast), Nonrigid	1.15	0.10
Austenitic Stainless Steels	8.03	—	Nylons, 6 & 66	1.13	0.05
Carbon and Low Alloy Steels	7.84	—	Ethyl Cellulose	1.13	0.03
Stainless Steels (cast)	7.77	0.24	Mod Polystyrenes Impact Res	1.04	0.04
Ingot Iron	7.76	—	Nitrile Rubber	1	—
Martensitic Stainless Steels	7.76	—	High Density Polyethylenes	0.96	0.01
Tin-Base Babbitts	7.55	0.21	Styrene-Butadiene Rubber	0.94	—
Aluminum Bronzes (cast)	7.48	0.08	Natural Rubber	0.93	—
Austenitic Nodular Irons	7.43	—	Low Density Polyethylenes	0.92	0.01
Tin and Its Alloys	7.29	0.03	Butyl Rubber	0.9	—
Malleable Irons	7.21	0.08	American Woods	0.53	0.16
Gray Irons	7.21	—	Epoxy Foamed-in-Place	0.51	0.11
Zinc and Its Alloys	7.17	0.01	Sheet Felts	0.473	0.217
Wrought and Nodular Irons	6.98	0.15	Cellular Polyethylene	0.47	—
Zinc Alloys (cast)	6.65	—	Prefoamed Epoxy	0.328	0.280
Zirconium	6.65	—	Neoprene Flexible Foam	0.321	0.160
Vanadium	6.38	—	Filter Felts	0.313	0.169
Titanium and Its Alloys	4.60	0.17	Fused Silica Glass	0.29	—
Whitewares	3.08	0.78	Flexible Nitrile Foam	0.281	0.120
Aluminum and Its Alloys	2.73	0.10	96% Silica Glass	0.26	—
Glass Fiber	2.54	—	Prefoamed Silicone Rubber	0.256	—
Phenolics, Electrical	2.37	0.63	Aluminum Silicate Glass	0.252	—
Polytetrafluoroethylene	2.2	0.1	Soda-Lime Glass	0.247	0.002
Alkyds, GP	2.20	0.04	Roll Felts	0.245	0.092
Molybdenum	2.2	—	Lead Silicate Glass	0.227	0.077
Polytrifluorochloroethylene	2.12	0.03	Silicone Rubber Foamed-in-Place	0.208	0.016
Allyls (cast)	2.05	0.75	Urethane Rubber Foamed-in-Place	0.204	0.197
Alkyds, High Strength	2.04	0.04	Urethane Flexible Foam	0.168	0.152
Melamines, Glass Fiber-Filled	1.95	0.05	Prefoamed Modified Polystyrene	0.125	0.015
Uranium	1.91	—	Latex Flexible Foam	0.104	0.008
Silicone Plastics	1.82	0.18	Cellular Cellulose Acetate	0.096	0.032
Magnesium Alloys (cast)	1.81	0.04	Phenolic Foamed-in-Place	0.096	0.064
Hard Rubber, Low Moisture Abs	1.8	—	Polystyrene Foamed-in-Place	0.096	0.064
Magnesium Alloys	1.77	—	Mod Polystyrenes, Ht & Cml Res	0.08	0.03
Melamines, Mineral- or Cellulose-Filled	1.71	0.29	Styrene-Butadiene Flexible Foam Rubber	0.072	—
Vinylidene Chloride	1.71	0.04	Vinyl Flexible Foam	>0.064	—
Hard Rubber, High Dielec Str	1.71	—	Prefoamed Polystyrene	0.048	0.019
Phenolics, Shock or Ht Res	1.67	0.33	Prefoamed Urea	0.016	0.003
Hard Rubber, High Ht Res	1.65	—			
Carbon and Graphite	1.57	0.07			

Thermal Conductivity[a]

Btu/hr/sq ft/°F/ft

Material ↓	Average	Range, ±
Cobalt	479	—
Silver	242	—
Copper[b]	211	—
Gold	172	—
Beryllium Copper[b]	105	—
Aluminum and Its Alloy[b]	97.8	30.2
Tungsten	96	—
Soft Leads	90.6	—
Plain Brasses[b]	88	21
Molybdenum	84	—
Graphite	78.8	8.0
Phosphor Bronzes[b]	74.5	45.5
Natural and Silicone Rubbers	67	—
Tin Brasses[b]	65.5	1.5
Zinc and Its Alloys	61.4	0.8
Inconel[b]	61	—
Aluminum Brass	58	—
Rhodium	50	—
Platinum	42	—
Palladium	41	—
Ingot Iron	38	—
Grade A Tin[b]	37	—
Nickel Steels	36.5	2.3
Wrought Iron	36	—
Nickel	35.1	0.9
Iridium	34	—
Tin Foil[b]	34	—
Tantalum	32	—
Nitriding Steels	30	—
Standard Malleable Iron[b]	29.5	—
Gray Irons	29	5
Aluminum Bronzes (cast)	27.5	5.5
Carbon and Low Alloy Steels	27	—
Nickel-Chromium-Molybdenum Steels	21.7	—
Nickel Silvers[b]	21.5	—
Thorium[b]	21.4	—
Nodular Irons	19	1
Hard Lead Alloys	17.5	1.5
Martensitic Stainless Steels	16.4	4.8
Nickel Silvers (cast)[b]	15	1
Uranium[b]	14.5	—
Lead-Base Babbitts	14	—
Monel	13.1	2.3
Tantalum Carbide[b]	12.8	—
Alumina Whitewares	11.8	2.2
Zirconium Carbide[b]	11.8	—
High Alloy Steels (cast)	11.4	3.8
Stainless Steels (cast)	11.3	3.2
Duranickel	11	2
Titanium Carbide[b]	9.92	—
Titanium	9.8	—
Zirconium	9.6	—
Beryllia[c]	9.53	—
Austenitic Stainless Steels	9.4	—
Inconel	8.7	—
Columbium Carbide[b]	8.22	—
Low Expansion Nickel Alloys	6.48	0.43
Titanium Alloys	5.8	0.9
Calcia[c]	4.12	—
Carbon	4	1
Zircon Whitewares	3.24	—
Forsterite	2.17	0.23
Cordierite and Steatite	1.68	0.72
Mullite[c]	1.55	—
Magnesia[c]	1.48	—
Alumina Refractory[c]	1.37	—
Standard Electrical Whitewares	1.22	0.35
Spinel and Zircon Refractories[c]	1.21	—
Low Density Polyethylenes, Melt Index <26	0.91	—
Silica Glass	0.8	—
Borosilicate Glass	0.67	—
Zirconia[c]	0.53	—
Soda-Lime Glass	0.53	—
Silicones—Plastics	0.529	0.441
Alkyds, G-P	0.475	0.125
Lead Silicate Glass	0.475	0.025
Polyvinyl Alcohol	0.46	—
Melamines, Filled	0.33	0.08
Phenolics, Electrical	0.29	0.05
Alkyds, High Str	0.25	0.05
Cellular Polyethylene	0.25	0.05
Phenolics, Shock and Ht Res	0.243	0.147
Plastics Laminates, GP	0.23	0.06
Ureas	0.207	0.037
Low Density Polyethylene, Melt Index 200	0.19	—
Plastics Laminates, Mech & Elec	0.17	—
Roll Felts	0.16	0.14
Nylons, Soluble	0.16	—
Cellulose Acetate and Propionate	0.145	0.045
Nitrile Rubber	0.143	—
Polytetrafluoroethylene	0.142	—
Phenolics, GP	0.133	0.037
Cellulose Nitrate Sheet	0.133	—
Ethyl Cellulose	0.129	0.038
Acrylics (cast)	0.125	0.025
Nylons 6, 66 and 610	0.12	0.02
Acrylics	0.120	—
Allyls (cast)	0.118	0.003
Neoprene Rubber	0.112	—
Polyester (cast), Rigid	0.11	0.01
Epoxies (cast)	0.101	0.005
Asbestos Fiber	0.097	—
Polyvinyl Formal	0.089	—
Polyvinyl Chloride	0.085	0.015
Rubber Phenolics	0.08	0.04
Polystyrenes, GP	0.069	0.011
Epoxy Foamed-in-Place	0.067	—
Glass Fiber	0.065	0.035
Modified Polystyrenes	0.054	0.006
Vinylidene Chloride	0.053	—
Butyl Rubber	0.053	—
Polytrifluorochloroethylene	0.035	—
Prefoamed Epoxy	0.034	0.120
Cellular Cellulose Acetate	0.026	0.002
Urethane Rubber Foamed-in-Place	0.025	0.005
Neoprene Flexible Foam	0.025	0.004
Silicone Rubber Foam	0.025	—
Latex and Nitrite Flexible Foams	0.023	0.002
Prefoamed Polystyrene	0.022	0.002
Phenolic Foamed-in-Place	0.021	0.002
Polystyrene Foamed-in-Place	0.020	0.002
Styrene—Butadiene Flexible Foam	0.018	—
Prefoamed Urea	0.016	0.002
Ceramic Fiber	0.015	0.004

[a]Values at temperatures between 120 and 212 F except where noted (exact temperature can be found in appropriate *Properties of Materials* section).
[b]Value at room temperature.
[c]Value at temperature >1800 F.

Coefficient of Thermal Expansion[a]

10^{-6} in./in./°F

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Polyethylene[d]	89.5	20.5	Molybdenum Steels[b]	8.3	—
Vinylidene Chloride[d]	87.8	—	Carbon Steels (cast)[b]	8.3	—
Polyvinyl Butyral[d]	85.5	41.5	Low Alloy Steels (cast)[b]	8.15	0.15
Ethyl Cellulose[d]	82.5	27.5	High Carbon Steels[b]	8.1	—
Cellulose Propionate[d]	80	10	Chromium-Vanadium Steels	8.1	—
Cellulose Acetate Butyrate[d]	75	15	Manganese Steels[b]	7.9	—
Mod Polystyrenes, Extra High Impact[d]	73	26	Gold	7.9	—
Cellulose Acetate[d]	67	23	Magnesia[c]	7.78	—
Nylon 6[d]	58.5	12.5	Nickel and Its Alloys	7.7	1.3
Cellulose Nitrate Sheet[d]	55	11	Calcia[c]	7.55	—
Polytetrafluoroethylene[d]	55	—	Martensitic Stainless Steels[b]	6.9	0.4
Nylon 66 and 610[d]	55	—	Ingot Iron	6.8	—
Polyvinyl Alcohol[d]	52.6	13.9	Cobalt[d]	6.8	—
Acrylics (cast)[d]	50	—	Wrought Iron	6.7	—
Polyester (cast), Rigid[d]	47.5	8.5	Nodular Irons	6.6	—
Phenolics (cast), Decorative[d]	44	11	Standard Malleable Irons	6.6	—
Allyls (cast)[d]	42	14	Nitriding Steels[b]	6.5	—
Mod Polystyrenes, Med & High Impact[d]	40	7	Palladium	6.5	—
Hard Rubber[d]	40	—	Titanium Alloys[b]	6.4	0.7
Polytrifluorochloroethylene[d]	38.8	—	Thorium[d]	6.2	—
Phenolics (cast), Mech & Cml[d]	38.5	5.4	Gray Irons	6	—
Polystyrenes, GP[d]	38.5	5.5	Ruthenium[d]	5.1	—
Epoxies (cast)[d]	38.3	11.7	Titanium[b]	5.8	—
Mod Polystyrenes, Ht & Cml Res[d]	38	—	Beryllium Carbide[b]	5.8	—
Acrylics[d]	35	5	Beryllia & Thoria[c]	5.28	—
Prefoamed Polystyrene[d]	35	15	Plastics Laminates, Mech[d]	5.2	0.9
Plastics Laminates, GP[d]	34.5	23.5	Spinel[c]	5	—
Polysulfide-Epoxy (cast)[d]	33	22	Soda-Lime Glass	4.95	0.15
Polyvinyl Chloride, Rigid[d]	30.5	2.5	Lead Silicate Glass	4.9	0.2
Silicones Plastics, GP[d]	30.1	2.2	Platinum	4.9	—
Urethane Rubber Foamed-in-Place[d]	29.5	14.5	Vanadium[d]	4.8	—
Epoxy Foamed-in-Place[d]	25.2	14.8	Forsterite	4.72	—
Silica, Crystalline	23.9	—	Rhodium[d]	4.6	—
Silicone Rubber Foamed-in-Place[d]	22.5	2.5	Tantalum Carbide[b]	4.6	—
Cellular Cellulose Acetate[d]	22.5	2.5	Silicone Plastics, High Impact[d]	4.5	—
Melamines, Filled[d]	21.1	10.6	Plastics Laminates, Elec[d]	4.45	1.35
Phenolics, GP	20.8	4.2	Alumina Refractory[c]	4.4	—
Alkyds[d]	20	10	Titanium Carbide[b]	4.1	—
Prefoamed Epoxy[d]	19	3	Columbium[d]	4	—
Zinc and Its Alloys[d]	18.9	0.5	Tantalum[d]	3.8	—
Soft Leads[d]	16.3	—	Iridium[d]	3.8	—
Tellurium Lead[d]	16	—	Zirconium Carbide[b]	3.7	—
Phenolics, Shock and Ht Res[d]	15.6	7.4	Steatite	3.66	0.33
Hard Lead Alloys	15.2	0.8	Osmium[d]	3.6	—
Zinc Alloys (cast)	15.2	—	Hafnium[d]	3.4	—
Rubber Phenolics[d]	15.1	6.9	Tungsten Carbide[b]	3.35	0.05
Magnesium Alloys	15	—	Alumina Whitewares	3.21	0.45
Aluminum and Its Alloys	13.9	0.6	Zirconium[d]	3.1	—
Ureas[d]	13.6	1.4	Zirconia[c]	3.06	—
Grade A Tin	13	—	Zircon Refractory[c]	3.06	—
Lead-Base Babbitts	12.7	1.9	Molybdenum[d]	3	—
Phenolics, Electrical[d]	12.5	1.9	Silicon Carbide[b]	2.6	—
Uranium	12.1	—	Boron Carbide[b]	2.5	—
Silver	10.9	—	Mullite[c]	2.5	—
Copper and Its Alloys	10.4	1.4	Aluminum Silicate Glass	2.3	—
Austenitic Nodular Irons	10.4	—	Tungsten[d]	2.2	—
Austenitic Stainless Steels[d]	9.7	0.2	Borosilicate Glass	2.15	0.35
Nickel Silvers	9.15	0.15	Cordierite	2.08	—
Nickel and Its Alloys (cast)[b]	9.03	0.17	Standard Electrical Whitewares	2	—
High Alloy Steels (cast)[b]	8.45	2.05	Zircon Whitewares	1.57	0.27
Stainless Steels (cast)[b]	8.4	2.0	Carbon	1.4	0.1
Free-Cutting Steels[b]	8.4	—	Graphite	1.15	0.15
Medium and Low Carbon Steels[b]	8.35	0.05	Silica Glass	0.37	0.07
			Silica, Vitreous	0.28	—

[a]Values for a temperature *range* except where noted. The lower temperature is room temperature. The higher temperature is a value between 212 and 750 F except where noted.
[b]Value for a temperature range between room temperature and 1200-1650 F.
[c]Value for a temperature range between room temperature and 2200-2875 F. [d]Value at room temperature only.

Melting Points of Metals and Ceramics

Fahrenheit

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Tungsten	6152	—	Fused Silica Glass	3050	—	Austenitic Nodular Irons	2250	—
Thoria	6000	—	Titanium Alloys	2866	136	Other Nodular Irons	2100	50
Tantalum	5425	—	Palladium	2829	—	Uranium	2071	—
Magnesia	5070	—	Ceramic Fiber	2800	—	Glass Fiber	2000	500
Osmium	4890	—	96% Silica Glass	2800	—	Copper	1960	20
Molybdenum	4760	—	Ingot Iron	2794	—	Gold	1945	—
Calcia	4710	—	Wrought Iron	2750	—	Copper Alloys	1790	160
Zirconia	4710	—	Low and Medium Carbon			Silver	1761	—
Beryllia	4620	—	Steels	2735	35	Aluminum Silicate		
Ruthenium	4530	—	Nickel-Chromium-			Glass	1675	—
Iridium	4450	—	Molybdenum Steels	2740	—	Borosilicate, Lead Sili-		
Zircon Refractory	4390	—	Cobalt	2723	—	cate and Soda-Lime		
Columbium	4380	—	Martensitic Stainless			Glasses	1290	210
Spinel	3830	—	Steels	2650	150	Aluminum and Its Alloys	1070	140
Alumina Refractory	3660	—	Stainless Steels (cast)	2650	100	Magnesium Alloys	1010	190
Rhodium	3571	—	Nickel	2620	10	Zinc and Its Alloys	756	36
Hafnium	3400	—	Austenitic Stainless			Soft Lead	620	3
Zirconium	3355	—	Steels	2600	50	Tin-Base Babbitts	570	220
Mullite	3330	—	Nickel Steels	2600	20	Hard Lead Alloys	550	60
Platinum	3224	—	Duranickel	2580	35	Pewter	520	45
Silica, Vitreous	3140	—	High Alloy Steels (cast)	2550	200	Lead-Base Babbitts	500	40
Titanium	3135	—	Nickel (cast)	2520	75	White Metal	475	—
Vanadium	3100	—	Asbestos Fiber	2470	300	Hard Tin	443	3
Thorium	3074	—	Nickel Alloys	2450	150	Tin Foil	390	—

Maximum Service Temperatures of Plastics and Rubber

Fahrenheit

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Silicone Rubber	550	—	Plastics Laminates, Elec	280	120	Polyvinyl Chloride, Non-		
Polytetrafluoroethylene	500	—	Cellular Cellulose Acetate	270	75	rigid	180	40
Silicone Plastics, GP	450	—	Polysulfide-Epoxy (cast)	270	25	Mod Polystyrenes, Ht &		
Silicones, High Impact	450	—	Polyester (cast), Rigid	270	25	Cml Res	180	8
Fluorinated Acrylic			Plastics Laminates, GP	270	25	Natural Rubber	180	—
Rubber	450	—	Urethane Rubber			Styrene-Butadiene		
Polytrifluorochloro-			Foamed-in-Place	270	25	Rubber	180	—
ethylene	380	—	Rubber Phenolics	260	45	Neoprene Flexible Foam	180	—
Diallyl Phthalate	370	75	Melamines, Fabric-Filled	250	—	Polystyrene Foamed-in-		
Phenolics, Shock and			Nitrile Rubber	250	—	Place	180	—
Ht Res	350	100	Polysulfide Rubber	250	—	Acrylics (cast)	170	30
Melamines, Glass-Fiber			Neoprene Rubber	240	—	Acrylics	170	18
Filled	350	50	Urethane Rubber	240	—	Ureas	170	—
Nylon, Glass Fiber-Filled	350	50	Nylon 6	220	25	Polystyrenes, GP	160	20
Alkyds, High Strength	350	—	Polyester (cast), Nonrigid	220	25	Polyvinyl Chloride, Rigid	160	8
Phenolics, Electrical	325	75	Plastics Laminates,			Prefoamed Polystyrene	160	5
Alkyds, GP	320	25	Mech	220	25	Latex Flexible Foam	160	—
Phenolics, GP	320	25	Nylon 610	220	—	Styrene-Butadiene		
Prefoamed Epoxy	320	25	Hard Rubber, GP	220	—	Flexible Foam	160	—
Melamines, Cellulose or			Polymethylstyrene	210	1	Polyvinyl Formal	150	17
Mineral-Filled	300	95	Melamines, Unfilled	210	—	Mod Polystyrenes, Med		
Epoxies (cast)	300	—	Butyl Rubber	210	—	& High Impact	140	20
Allyls (cast)	300	—	Nitrile Flexible Foam	210	—	Mod Polystyrenes, Extra		
Phenolic Foamed-in-			Urethane Flexible Foam	200	—	High Impact	140	15
Place	300	—	Prefoamed Urea	200	—	Nylons, Soluble	140	—
Nylon 66	290	12	Vinylidene Chloride	191	21	Polyvinyl Butyral	110	—

Electrical Resistivity[a]

Microhm-cm

Material ↓	Range
Polytrifluorochloroethylene	1.2×10^{24}
Polystyrenes, GP	10^{24}-10^{25}
Polyethylene	10^{23}-10^{25}
Nylons, Glass Fiber-Filled	4.9-5.7×10^{21}
Mod Polystyrenes, Med & High Impact	10^{21}-10^{23}
Acrylics (cast)	10^{21}
Aluminum Silicate Glass[b]	10^{21}
Fused Silica Glass[b]	10^{21}
Urethane Rubber Flexible Foam	6.8-8.3×10^{20}
Polystyrenes, Glass Fiber-Filled	1-67×10^{20}
Vinylidene Chloride	10^{20}-10^{22}
Mod Polystyrenes, Extra High Impact	10^{20}-10^{22}
Alumina Whitewares	10^{20}-10^{21}
Acrylics and Alkyds	10^{20}
Cordierite, Forsterite and Steatite	10^{20}
Lead Silicate Glass[b]	10^{20}
Polyvinyl Butyral	10^{20}
Polyvinyl Chloride, Rigid	10^{20}
Zircon Whitewares	10^{20}
Allyls (cast)	$>10^{19}$
Nylon 66	4.5×10^{19}
Mod Polystyrenes, Ht & Cml Res	10^{19}-10^{23}
Nylon 6	10^{19}-10^{21}
Standard Electrical Whitewares	10^{19}-10^{21}
Epoxy Foamed-in-Place	10^{19}
Polyesters (cast), Rigid	10^{19}
Epoxies (cast)	$>8 \times 10^{18}$
Phenolics, Electrical	6-10×10^{18}
Polysulfide-Epoxy (cast)	1.3-15×10^{18}
Phenolics (cast), Mech & Cml	1-7×10^{18}
Phenolics (cast), Decorative	1-3×10^{18}
Cellulose Propionate	10^{18}-10^{21}
Ethyl Cellulose	10^{18}-10^{20}
Borosilicate Glass[b]	10^{18}
Polyesters (cast), Nonrigid	10^{18}
Polytetrafluoroethylene	10^{18}
Polyvinyl Chloride, Nonrigid	4-7000×10^{17}
Phenolics (cast), Transparent	3×10^{17}
Polymethylstyrene	2.6-2600×10^{17}
Glass Fiber	2×10^{17}-10^{21}
Melamines, Glass Fiber-Filled	1-7×10^{17}
Cellulose Nitrate Sheet	1.0-1.5×10^{17}
Melamines, Cellulose and/or Mineral-Filled	10^{17}-10^{20}
Ureas	5-50×10^{16}
Cellulose Acetate	10^{16}-10^{19}
Phenolics, Shock and Ht Res	10^{16}-10^{19}
Cellulose Acetate Butyrate	10^{16}-10^{18}
96% Silica Glass[b]	$>4 \times 10^{15}$
Soda-Lime Glass[b]	4×10^{15}
Phenolics, GP	10^{15}-10^{19}
Melamines, Fabric-Filled	10^{15}-10^{18}
Diallyl Phthalate	1-250×10^{14}
Silicone Plastics	$>3.4 \times 10^{13}$
Rubber Phenolics	10^{12}-10^{17}
Silicon Carbide	1.07-2×10^{8}
Beryllium Carbide	1.1×10^{6}
Boron Carbide	3-8×10^{5}
Carbon	3500-4600
Graphite	800-1300
Vanadium Carbide	156
Gray Irons	125
Titanium Alloys	118
Titanium Carbide	105
Austenitic Nodular Irons	102
Inconel	98.1
Columbium Carbide	74
Austenitic Stainless Steels	72
Stainless Steels (cast)	71-90
High Alloy Steels (cast)	70-112
Nodular Irons	66-68
Zirconium Carbide	63.4
Titanium	55
Monel (cast)[c]	53.2-63.1
Monel	48.2-58.3
Low Expansion Nickel Alloys	48-81
Duranickel[c]	46.5
Martensitic Stainless Steels	40-72
Zirconium	40
Pearlitic Malleable Irons	38.2-41.2
Standard Malleable Irons	32
Nickel-Chromium-Molybdenum Steels[b]	30
Hafnium[c]	30
Nitriding Steels	27-29
Nickel Steels, Ann.[b]	27-29
Lead-Base Babbitts	25.6-28.7
Uranium	25-50
Vanadium	25
Hard Lead Alloys	22.0-27.1
Chromium-Vanadium Steels	21.0
Nickel (cast)[c]	20.8
Soft Leads	20.6
Tantalum Carbide	20
Manganese-Silicon and Manganese-Nickel-Chromium-Molybdenum Steels	19-20
Molybdenum Steels	19
Medium Carbon Steels	19
Thorium	18
High Carbon Steels	18
Manganese Steels	17
Low Alloy Steels	15-20
White Metal	15
Platinum[c]	14.9
Free-Cutting Steels	14.3
Low Carbon Steels	14.3
Magnesium Alloys (cast), Sol'n Tr	14.0-17.5
Carbon Steels (cast)	13-16
Columbium	13
Tungsten Carbide	12-81
Tantalum	12.4
Tin Foil	12
Inconel (cast)[c]	11.6-12.6
Grade A Tin	11.5
Palladium	10.8
Ingot Iron	9.7
Nickel[c]	9.5
Osmium	9.5
Admiralty Metal, Ann	8.9
Ruthenium[c]	7.6
Aluminum Bronzes (cast)	7.5-13.5
Aluminum Brass, Ann	7.5
Manganese Bronze, Ann	7.2
Zinc Alloys (cast)	6.37-6.54
Zinc Alloys (HR)	6.22-6.31
Zinc (CR)	6.10
Magnesium Alloys (cast)	6.6-17
Naval Brass, Ann	6.6
Yellow Brass, Ann	6.4
Muntz Metal, Ann	6.2
Cartridge Brass, 70% Ann	6.2
Zinc (HR)	6.06
Aluminum and Its Alloys, T4	5.75
Tungsten[c]	5.5
Low Brass, 80%, Ann	5.4
Iridium	5.3
Molybdenum[c]	5.2
Magnesium Alloys	5-14.5
Beryllium Coppers, Ann	4.82-5.82
Rhodium	4.51
Red Brass, 85%, Ann	4.7
Commercial Bronze, 90%, Ann	3.9
Phosphor Bronzes, Ann	3.6-16
Gilding, 95%, Ann	3.1
Aluminum and Its Alloys, Ann	2.93-5.94
Gold[c]	2.35
Copper, Ann	1.71-2.03
Silver	1.59

[a] Values or ranges at room temperature except where noted.
[b] Value or range at a temperature between 120 and 212 F (exact temperature or temperature range can be found in appropriate *Properties of Materials* section).
[c] Value or range at 32 F.

Modulus of Elasticity in Tension[a]

100,000 psi

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Osmium	800	—	Fused Silica Glass	100	—
Magnesium Alloys (cast)	650	—	96% Silica Glass	97	—
Ruthenium	600	—	Soda-Lime Glass	95	5
Tungsten	500	—	Borosilicate Glass	83	15
Molybdenum	420	—	Lead Silicate Glass	83	7
Rhodium 420	420	—	Pewter	77	—
Alumina Whitewares	380	30	Tin-Base Babbitts	74.5	1.5
Inconel	310	—	Iridium	74	—
Cobalt	300	—	Cordierite	70	—
Nickel	300	—	Magnesium Alloys	65	—
Duranickel	300	—	Grade A Tin	62.5	2.5
Uranium	300	—	Foamed-in-Place Epoxy	60	—
Carbon Steels (cast)	299	2	Lead-Base Babbitts	42	—
Ingot Iron	298	—	Phenolics, Electrical	40	10
Carbon and Low Alloy Steels	295	5	Phenolics, Shock and Ht Res	20.5	12.5
Wrought Iron	290	—	Lead and Its Alloys	20	—
Martensitic Stainless Steels	290	—	Carbon	19.5	3.5
Pearlitic Malleable Irons	280	—	Haynes Stellite 21	16.8	—
Austenitic Stainless Steels	280	—	Melamines, Filled	14.7	4.8
Tantalum	270	—	Ureas	14.5	1.5
High Alloy Steels (cast)	270	20	Polystyrenes, Glass Fiber-Filled	12	—
Stainless Steels (cast)	265	25	Diallyl Phthalate	11.5	5.5
Monel	260	—	Graphite	11	3
Standard Malleable Irons	250	—	Phenolics, GP	10.5	2.5
Inconel (cast)	240	10	Rubber Phenolics	6.5	2.5
Monel (cast)	236	6	Polyvinyl Formal	6	1
Nodular Irons	235	15	Epoxies (cast)	4.95	0.45
Low Expansion Nickel Alloys	225	15	Phenolics (cast), Mech & Cml	4.5	0.5
Nickel (cast)	215	—	Polystyrenes, GP	4.5	0.5
Platinum	210	—	Acrylics	4.25	0.75
Zircon Whitewares	210	—	Nylon 66	4.05	0.05
Hafnium and Vanadium	200	—	Polyesters (cast), Rigid	4.0	2.5
Beryllium Coppers	190	—	Mod Polystyrenes	4	2
Austenitic Nodular Irons	185	—	Phenolics (cast), Decorative	3.75	0.75
Nickel Silvers	180	20	Polyvinyl Butyral	3.75	0.25
Copper	170	—	Nylons 6 and 610	2.55	1.05
Palladium	170	—	Allyls (cast)	2.5	0.5
Aluminum and Phosphor Bronzes	165	15	Polytrifluorochloroethylene	2.45	0.55
Plain Brasses	160	10	Cellulose Nitrate Sheet	2.05	0.15
Tin and Aluminum Brasses	155	5	Ethyl Cellulose	2.0	1.5
Titanium and Its Alloys	154	5	Phenolics (cast), Transparent	2	1
Gray Irons	145	55	Polysulfide-Epoxy (cast)	1.75	1.74
Steatite	145	15	Vinylidene Chloride	1.35	0.60
Zirconium	140	—	Cellulose Propionate	1.1	0.6
Gold	120	—	Polytetrafluoroethylene	0.515	0.135
Silver	110	—	Nylons, Soluble	0.38	—
Aluminum and Its Alloys	104	4	Low Density Polyethylenes	0.235	0.035
Thorium	100	—	Polyvinyl Chloride, Nonrigid	0.017	0.013
Standard Electrical Whitewares	100	—			

[a]At room temperature.

Tensile Strength[a]

1000 psi

Material ↓	Average	Range, ±
Rhodium, CW	300	—
Manganese-Silicon & Manganese-Nickel-Chromium-Molybdenum Steels, H & T (800 F)	225	33
Nickel-Chromium-Molybdenum Steels, H & T (800 F)	215	5
Stainless Steels (cast), H & T	210	10
Glass Fiber	208	4
Beryllium Coppers, CW & Ht Tr	195	15
Nitrided Steels, H & T	190	—
Molybdenum Steels, H & T (300-1475 F)	188	80
Martensitic Stainless Steels, H & T	187	98
Tungsten, CW	185	120
Monel, Age H	185	15
Beryllium Coppers, Ann. & Ht Tr	175	10
Titanium Alloys, Ht Tr	170	—
High Carbon Steels, H & T (700 F)	169	20
Nickel-Chromium-Molybdenum Steels, H & T (800 F)	168	46
Inconel, Age H	167	13
Asbestos Fiber	158	142
Low Alloy Steels (cast), H & T	155	45
Austenitic Stainless Steels, CW	147	38
Molybdenum, CW	147	28
Chromium-Vanadium Steels, H & T (300-1200 F)	146	41
Tantalum, CW	145	35
Titanium Alloys, Ann	137	18
Monel (cast), Ann. & Aged	132	13
Aluminum Silicate Glass	125	17
High Carbon Steels (HR)	127	—
Nickel Steels, H & T (1000 F)	122	18
Sheet Felts	122	10
Inconel, Ann	120	10
Manganese Steels, H & T (300-1000 F)	118	18
Phosphor Bronzes, Hard	117	11
Low Expansion Nickel Alloys, CW	115	25
Molybdenum Steels, CD	113	24
Columbium, CW	113	17
Vanadium, CW	113	—
Roll Felts	112	13
Phosphor Bronzes, Hard	111	36
Manganese Steels, CD	110	9
Medium Carbon Steels, H & T (1000 F)	109	11
High Carbon Steels, Ann	108	11
Molybdenum, Ann	107	23
Nickel-Chromium-Molybdenum Steels (43xx), Ann	107	12
High Alloy Steels (cast), Norm. & T	107	—
Nodular Irons	105	45
Duranickel, Ann	105	15
Aluminum Bronzes (sand cast), H & T (1000-1150 F)	102	13
Nickel Steels, CD	102	8
Nickel Silvers, Extra Hard	100	8
Carbon Steels (cast), H & T	100	—
Cobalt, CW	100	—
Nickel Steels (HR)	98	17
Molybdenum Steels, CD & Ann	98.5	10.5
Cobalt (sintered)	98.5	—
Austenitic Stainless Steels, Ann	97.5	12.5
Manganese Steels, Ann	97	13
Stainless Steels (cast), Ann	96	1
Martensitic Stainless Steels, Ann	95	30
High Alloy Steels (cast), Ann	95	—
Medium Carbon Steels, CW	94	9
Titanium, Ann	94.5	5.5
Inconel (cast)	92.5	27.5
Nickel-Chromium-Molybdenum Steels (86xx, 87xx), Ann	91	14
Free-Cutting Steel, CD	90	20
Nickel Steel, Ann	90.5	13.5
Uranium	90	—
Medium Carbon Steels (HR)	89	9
Monel, Ann	87.5	17.5
Zirconium, CW	86	4
Manganese Bronze, Half Hard	84	—
Cartridge Brass, 70%, Hard	76	—
Low Expansion Nickel Alloys, Ann.	76	6
Tantalum, Ann	75	25
Pearlitic Malleable Irons	75	15
Naval Brass, Half Hard	75	—
Low Brass, 80%, Hard	74	—
Yellow Brass, Hard	74	—
Ingot Iron, CD	73	—
Rhodium, Ann	73	—
Beryllium Coppers, CW	72	—
Vanadium, Ann	72	—
Beryllium Coppers, Ann	70	10
Aluminum and Its Alloys, T6	70	—
Red Brass, 85%, Hard	70	—
Muntz Metal, Half Hard	70	—
Low Carbon Steels, CW	69	13
Manganese Bronze, Ann	65	—
Austenitic Nodular Irons	63	5
Nickel, Ann	62.5	12.5
Low Carbon Steels (HR)	60.5	9.5
Aluminum Brass, Ann	60	—
Cobalt, Ann	56	19
Gilding, 95%, Hard	56	—
Nickel (cast)	57.5	7.5
Naval Brass, Ann	57	—
Nickel Silvers, Ann	55	6
Standard Malleable Irons	55	5
Commercial Bronze, 90%, Hard	54	—
Muntz Metal, Ann	54	—
Silver, CW	54	—
Phosphor Bronzes, Ann	53	13
Columbium, Ann	53.5	5.5
Admiralty Metal, Ann	53	—
Roll Felts	50	33
Copper, Hard	50	—
Nickel Silvers (sand cast)	47.5	17.5
Cobalt (cast)	47.7	13.3
Wrought Iron (HR)	47	—
Palladium, CW	47	—
Yellow Brass, Ann	46	—
Gray Irons (cast)	45	30
Zirconium, Ann	44	15
Zinc Alloys (die cast)	44.3	3.3
Ingot Iron (HR)	44	—
Cartridge Brass, 70%, Ann	44	—
Ingot Iron, Ann	42	—

[a]At room temperature.

Tensile Strength—concluded

1000 psi

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Low Brass, 80%, Ann.	42	—	Phenolics (cast), Decorative	6.1	1.1
Magnesium Alloys (cast), Sol'n Tr & Aged	40	—	Vinylidene Chloride	6	2
Magnesium Alloys (forged)	41	5	Phenolics, Electrical	6	1
Platinum, CW	39.5	5.5	Urethane Rubber (gum)	>5	—
Red Brass, 85%, Ann.	39	—	Diallyl Phthalate	5.85	1.15
Zinc Alloys (CR)	38.5	7.5	Hard Rubber, High Dielec Str	5.8	—
Magnesium Alloys (extr)	37.5	11.5	Allyls (cast)	5.75	1.25
Thorium	37.5	—	Nylons, Soluble	5.6	1.8
Zinc Alloys (HR)	32	8	Hard Lead Alloys (chill cast)	5.4	2.0
Copper, Ann.	32	—	Hard Rubber, Low Moisture Abs	5.4	—
Gold, CW	32	—	Hard Rubber, GP	5.15	3.15
Nickel Silvers (sand cast)	30	2	Mod Polystyrenes, Med & High Impact	5.15	1.65
Palladium, Ann.	30	—	Polytrifluorochloroethylene	5.15	0.55
Vinylidene Chloride, Oriented	27.5	12.5	Ethyl Cellulose	5	2
Alumina Whitewares	27.5	7.5	Standard Electrical Whitewares	4.75	2.25
Zinc (CR)	26	5	Silicone Plastics, High Impact	4.7	0.3
Zinc (HR)	24.2	4.8	Cellulose Acetate, Medium	4.6	1.9
Plastics Laminates, GP	22.2	14.8	Cellulose Propionate	4.5	3.0
Silver, Ann.	22	—	High Density Polyethylenes	4.5	1.0
Platinum, Ann.	21.5	4.5	Cellulose Acetate Butyrate	4.35	2.45
Gold, Ann.	19	—	Silicone Plastics, GP	4.15	0.15
Gold (cast)	18	—	Natural Rubber	4.0	0.5
Nylons, Glass Fiber-Filled	16	4	Hard Tin (CR)	4	—
Plastics Laminates, Electrical	15.2	7.8	Hard Rubber, High Arc Res	4	—
Silver (cast)	15	—	Mod Polystyrenes, Extra High Impact	3.75	0.75
Plastics Laminates, Mechanical	14	6	Nitrile Rubber, Black	3.75	0.75
Polystyrenes, Glass Fiber-Filled	12.2	2.3	Phenolics (cast), Transparent	3.5	1.0
Nylons 66 and 6	11.4	1.2	Alkyds, GP	3.5	0.5
Tin-Base Babbitts (chill cast)	10.6	1.4	Polyvinyl Alcohol	3	2
Forsterite	10.3	—	Styrene-Butadiene Rubber, Black	3.0	0.5
Epoxies (cast)	10.2	1.8	Natural Rubber (gum)	3.0	0.5
Mod Polystyrenes, Ht & Cml Res	10.5	0.5	Cordierite	3	—
Polyvinyl Formal	10	1	Grade A Tin (CR)	2.8	—
Steatite	9.9	5.1	Butyl Rubber	2.75	0.25
Acrylics	9.25	1.25	Polyvinyl Chloride, nonrigid	2.25	1.25
Tin Foil (CR)	8.7	—	Polytetrafluoroethylene	2.25	0.75
Lead-Base Babbitts (chill cast)	8.65	1.85	Grade A Tin, Ann.	2.2	—
Pewter, Ann.	8.6	—	Soft Leads (chill cast or extr)	2.1	0.1
Nylon 610	8.5	—	Low Density Polyethylenes, Melt Index<26	1.95	0.55
Zircon Whitewares	8.25	3.75	Soft Leads (sand cast)	1.8	—
Acrylics (cast)	8	2	Polyesters (cast), Nonrigid	1.4	0.5
Alkyds, High Strength	8	2	Graphite	1.22	0.78
Polymethylstyrenes	7.8	1.2	Fluorinated Acrylic Rubber (gum)	1.2	—
Pewter (CR)	7.6	—	Polysulfide Rubber (gum)	>1	—
Melamines, Filled	7.5	2.5	Carbon	1.0	0.1
Ureas	7.5	2.5	Epoxy Foamed-in-Place	0.9	—
Phenolics (cast), Mech & Cml	7.5	1.5	Silicone Rubber (gum)	0.8	0.2
Phenolics, GP	7.5	1.0	Nitrile Rubber (gum)	0.7	0.2
Cellulose Nitrate Sheet	7.5	0.5	Cellular Polyethylene	0.67	—
White Metal (CR)	7.4	—	Prefoamed Modified Polystyrene	0.58	0.52
Polyvinyl Chloride, Rigid	7.25	1.75	Urethane Rubber Foamed-in-Place	0.50	0.49
White Metal (cast)	7.2	—	Styrene-Butadiene Rubber (gum)	0.25	0.05
Hard Rubber, Cml Res	7.17	—	Cellular Cellulose Acetate	0.15	0.03
Phenolics, Shock and Ht Res	7	3	Prefoamed Polystyrene	0.11	0.08
Polyesters (cast), Rigid	7	3	Vinyl Flexible Foam	0.10	0.09
Polystyrenes, GP	6.75	1.75	Polystyrene Foamed-in-Place	0.08	0.05
Hard Rubber, High Ht Res	6.75	—	Neoprene Flexible Foam	0.06	0.04
White Metal, Ann.	6.7	—	Phenolic Foamed-in-Place	0.039	0.035
Cellulose Acetate, Hard	6.55	1.95	Latex Flexible Foam	0.015	0.005
Polysulfide-Epoxy (cast)	6.5	3.5			
Rubber Phenolics	6.25	2.75			
Polyvinyl Butyral	6.25	2.25			

Elongation[a]

% in 2 in.

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Butyl Rubber (gum)	850	100	Zinc (CR)	40	10
Neoprene Rubber (gum)	850	50	Nickel Silvers, Ann.	40	9
Natural Rubber (gum)	800	50	Leaded Naval Brass, Ann.	40	—
Butyl Rubber, Black	750	100	Tellurium Lead (extr)	40	—
Urethane Rubber (gum)	640	110	Tin Foil (CR)	40	—
Natural Rubber, Black	600	50	Pewter, Ann.	40	—
Nitrile Rubber	575	125	Thorium	40	—
Thiokol Rubber (gum)	550	100	Hard Lead Alloys (rolled)	38	22
Neoprene Rubber, Black	550	50	Low Expansion Nickel Alloys, Ann.	38	3
Styrene-Butadiene Rubber	500	100	Monel, Ann.	37	13
Nylons, Soluble	450	150	Stainless Steels (cast), H & T	36	19
Polyvinyl Alcohol	450	150	Platinum, Ann.	35	5
Low Density Polyethylenes, Melt Index <26	425	300	Ingot Iron, Ann.	35	4
Latex Flexible Foam	380	—	Copper, Ann. Wire	35	—
Polyvinyl Chloride, Nonrigid	320	130	Grade A Tin (CR)	35	—
Cellular Polyethylene	310	—	Austenitic Stainless Steels, CW	34	26
Nylons 6 and 66	300	—	Manganese Bronze, Ann.	33	—
Fluorinated Acrylic Rubber (gum)	300	—	Polyvinyl Butyral	32	28
Silicone Rubber (gum)	230	170	Cellulose Acetate, Medium	32	15
Polytetrafluoroethylene	230	120	Palladium, Ann.	32	8
Vinyl Flexible Foam	190	110	Carbon Steel (cast), Ann.	32	—
Polyesters (cast), Nonrigid	170	140	Bast Fiber	31	19
Polymethylstyrene	130	70	Aluminum and Its Alloys, Ann.	31	14
Duranickel, Ann.	90	40	Zinc Alloys (HR)	30	20
Low Density Polyethylenes, Melt Index 200	90	10	Columbium, Ann.	30	—
Nylon 610	85	—	Soft Leads (sand cast)	30	—
White Metal, Ann.	70	—	Gold (cast)	30	—
Ingot Iron, CD	69	—	Chromium-Vanadium Steels, Norm. (1600-1650 F)	29	6
Hard Lead Alloys (extr)	66	9	Carbon Steels (cast), Norm.	29	1
Cartridge Brass, 70%, Ann.	66	—	White Metal (CR)	28	—
Yellow Brass, Ann.	65	—	Vanadium, Ann.	28	—
Admiralty Metal, Ann.	65	—	Nickel-Chromium-Molybdenum Steels (86xx, 87xx), Ann.	27	5
High Density Polyethylenes	62	38	Medium Carbon Steels (HR)	27	3
Mod Polystyrenes, Extra High Impact	60	40	Low Carbon Steels, CW	26	9
Silver (cast)	60	—	Nickel Steels, Ann.	26	5
Phosphor Bronzes, Ann.	59	11	Zirconium, Ann.	26	0.5
Polytrifluorochloroethylene	57	30	Monel (as cast)	25	24
Cellulose Acetate Butyrate	56	18	Tantalum. Ann.	25	15
Austenitic Stainless Steels, Ann.	55	5	Carbon Steels (cast), Norm. & T	25	1
Cellulose Propionate	55	5	Martensitic Stainless Steels, Ann.	24	11
Aluminum Brass, Ann.	55	—	Wrought Iron (HR)	24	—
Grade A Tin (cast)	55	—	Austenitic Nodular Irons	23	17
Low Brass, 80%, Ann.	52	—	Cellulose Acetate, Hard	23	17
Polysulfide-Epoxy (cast)	50	50	Manganese Steels, H & T (300-1000 F)	23	5
Nickel, Ann.	50	10	Low Alloy Steels (cast), Norm. & T.	23	3
Soft Leads (rolled)	50	7	Ingot Iron (HR)	23	—
Pewter (CR)	50	—	High Alloy Steels (cast), Ann.	23	—
Ingot Iron, Ann.	48	—	Nickel (cast)	22	8
Red Brass, 85%, Ann.	48	—	Vinylidene Chloride	22	8
Soft Leads (extr)	48	—	Medium Carbon Steels, H & T (1000 F)	22	5
Silver, Ann.	48	—	Aluminum Bronzes (sand cast)	21	14
Inconel, Ann.	47	8	Nickel Steels, CD	21	4
Zinc (HR)	47	8	Nickel-Chromium-Molybdenum Steels (43xx), Ann.	21	4
Naval Brass, Ann.	47	—	Manganese Steels, Ann.	21	3
Commercial Bronze, 90%, Ann.	45	—	Mod Polystyrenes, Med & High Impact	20	15
Copper, Ann.	45	—	Nickel Silvers (sand cast)	20	10
Gilding, 95%, Ann.	45	—	Medium Carbon Steels, CW	20	6
Gold, Ann.	45	—	Hard Lead Alloys (chill cast)	20	4
Muntz Metal, Ann.	45	—	Manganese-Silicon & Manganese-Nickel-Chromium-Molybdenum Steels, H & T (1200 F)	20	3
Grade A Tin, Ann.	45	—			
Soft Leads (chill cast)	43	4			
Beryllium Coppers, Ann.	42	8			
Nickel Silvers, Ann. Wire	42	8			
Cellulose Acetate, Soft	41	9			

[a]At room temperature.

Elongation—concluded

% in 2 in.

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Carbon Steels (cast), H & T	20	—	Cobalt (sintered)	13	—
Naval Brass, Half Hard	20	—	Titanium Alloys, Ht Tr	13	—
Low Expansion Nickel Alloys, CW	20	—	Uranium	13	—
Copper, Half Hard	19	6	Nodular Irons	12	12
High Carbon Steels, Ann	19	5	Manganese-Silicon & Manganese-Nickel-Chromium-Molybdenum Steels, H & T (800 F)	12	30
Manganese-Silicon & Manganese-Nickel-Chromium-Molybdenum Steels, Norm. (1600-1650 F)	19	5	Low Alloy Steels (cast), H & T	12	8
Monel, Ann. & Age H	19	5	Aluminum and Its Alloys, H18	12	3
Molybdenum Steel, CD & Ann	19	3	Cobalt, CW	5	3
Nitriding Steels, H & T (1200 F)	19	3	Beryllium Copper, CW & Ht Tr	5	3
Manganese Bronze, Half Hard	19	2.4–2.5	Lead-Base Babbitts (chill cast)	5	3
Titanium, Ann	18	4	Gilding, 95%, Hard	5	—
Aluminum and Its Alloys, H14	18	2	Commercial Bronze, 90%, Hard	5	—
Nickel-Silvers (sintered)	12	3	Red Brass, 85%, Hard	5	—
High Carbon Steels, H & T	12	2	Polyesters (cast), Rigid	5	—
Magnesium Alloys (cast), Sol'n Tr	11	1	Acrylics (cast)	4.5	2.5
Inconel (cast)	10	9	Magnesium Alloys (cast)	4	2
Aluminum and Its Alloys, H38	10	5	Sheet Felts	4	2
Aluminum Bronzes (sand cast), H & T (1000-1150 F)	10	5	Acrylics	4	1
Duranickel, Age H	10	5	High Alloy Steels (cast), Aged 48 Hr at 1800 F	4	—
Phosphor Bronzes, Hard	10	3	Gold, CW	4	—
Muntz Metal, Half Hard	10	—	Beryllium Coppers, Ann. & Ht Tr Wire	3.5	1.5
Magnesium Alloys (forged)	9.5	2.5	Hard Rubber, GP	3	1
Stainless Steels (cast)	8.5	6.5	Platinum, CW	3.0	0.5
Zinc Alloys (die cast)	8.5	1.5	Magnesium Alloys (cast), Sol'n Tr & Aged	3	2
Haynes Stellite 21 (cast)	8	—	Vanadium, CW	3	—
Red Brass, 85%, Half Hard Wire	8	—	Glass Fiber	2.8	0.9
Low Brass, 80%, Half Hard Wire	8	—	Hard Rubber, Cml Res	2.7	—
Cartridge Brass, 70%, Hard	8	—	Hard Rubber, High Ht Res	2.6	—
Yellow Brass, Hard	8	—	Hard Rubber, High Dielec Str	2.6	—
Pearlitic Malleable Irons	7.5	4.5	Inconel (cast), Ann. & Aged	2.5	1.5
Beryllium Coppers, Ann. & Ht Tr	7.5	4.5	Monel (cast), Ann. & Aged	2.5	1.5
Monel, Age H	7.5	2.5	Nickel Silvers, Extra Hard	2.5	0.5
Nylon, Glass Fiber-Filled	7.5	1.0	Roll Felts	2.5	0.5
Copper, Hard	7	1	Silver, CW	2.5	—
Low Brass, 80%, Hard	7	—	Polymethylstyrene	2.3	0.2
Cobalt, Ann	6.5	6.5	Cobalt (cast)	2	2
Zirconium (CW)	5.7	4.3	Beryllium Coppers, CW Wire	2	1
Molybdenum (sintered), Ann	5.5	1.5	Mod Polystyrenes, Ht & Cml Res	2	1
Zinc Alloys (CR)	17	3	Haynes Stellite 21, Aged 50 Hr at 1300 F	2	—
Standard Malleable Irons	17	8	Polystyrenes, GP	1.9	0.5
Chromium-Vanadium Steels, H & T (300-1200 F)	17	5	Hard Rubber, Low Moisture Abs	1.8	—
Aluminum and Its Alloys, T4	17	5	Rubber Phenolics	1.5	0.8
Nitriding Steels, H & T (1250 F)	17	—	Copper, Hard Wire	1.5	—
Martensitic Stainless Steels, H & T	16	14	Palladium, CW	1.5	—
Nickel-Chromium-Molybdenum Steels (86xx, 87xx), H & T (800 F)	16	5	Tantalum, CW	1.2	0.3
Stainless Steels (cast), Ann	16	2	Tungsten, CW	1	1
Polyvinyl Chloride, Rigid	15	10	Columbium, CW	1	—
Free-Cutting Steels, CD	15	5	Molybdenum (sintered), CW	1	—
Beryllium Coppers, CW	15	5	Inconel, Age H	1	—
Nitrided Steels, H & T	15	—	Zinc Alloys (chill cast)	1	—
Yellow Brass, Half Hard Wire	15	—	Ureas	1	—
Leaded Naval Brass, Half Hard	15	—	Hard Rubber, High Arc Res	1	—
Molybdenum Steels, H & T (300-1000 F)	14	7	Polystyrene, Glass Fiber-Filled	0.87	0.13
Titanium Alloys, Ann	14	4	Melamines, Fabric-Filled	0.7	0.1
Tin-Base Babbitts (die cast)	13	9	Phenolics, GP	0.6	0.2
Magnesium Alloys (extr)	13	5	Melamines, Cellulose or Mineral-Filled	0.45	0.15
Nickel-Chromium-Molybdenum Steels (43xx), H & T (800 F)	13	1	Phenolics, Shock and Ht Res	0.38	0.19
Aluminum and Its Alloys, H34	13	1	Phenolics, Electrical	0.31	0.22

Hardness of Metals and Ceramics[a]

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Columbium Carbide	9.5 Mohs	0.5	Nickel-Chromium-Molybdenum Steels (43xx), Ann.	210	27
Tungsten Carbide	9.5 Mohs	0.5	Medium Carbon Steels, H & T (1000 F)	210	3
Vanadium Carbide	9.5 Mohs	0.5	Low Expansion Nickel Alloys, CW	B101	2
Boron Carbide	9.3 Mohs	—	Martensitic Stainless Steels, Ann.	200	55
Silicon Carbide	9.2 Mohs	—	Manganese Steels, Ann.	200	22
Beryllium Carbide	9 Mohs	—	Molybdenum Steels, CD & Ann.	200	22
Tantalum Carbide	9 Mohs	—	Medium Carbon Steels, CW	200	19
Alumina Refractory	9 Mohs	—	High Carbon Steels, Ann.	200	19
Beryllia	9 Mohs	—	Cast Stainless Steels, Ann.	200	8
Alumina Whitewares	8.7 Mohs	0.2	Carbon Steels (cast), H & T	200	—
Titanium Carbide	8.5 Mohs	0.5	Nickel Silvers, Hard	B99	—
Zirconium Carbide	8.5 Mohs	0.5	Free-Cutting Steels, CD	190	40
Zircon Whitewares	8 Mohs	—	Nickel Steels (HR)	190	35
Spinel	8 Mohs	—	High Alloy Steels (cast)	190	29
Forsterite	7.5 Mohs	—	Medium Carbon Steels (HR)	190	24
Steatite	7.5 Mohs	—	Nickel-Chromium-Molybdenum Steels (86xx, 87xx), Ann.	190	23
Zirconia	7.5 Mohs	0.5	Stainless Steels (cast)	190	21
Zircon Refractory	7.5 Mohs	—	Nickel Steels, Ann.	180	29
Standard Electrical Whitewares	7.2 Mohs	0.2	Low Alloy Steels (cast), Norm. & T	180	29
Cordierite	7 Mohs	—	High Alloy Steels (cast), Ann.	180	—
Silica, Crystalline	7 Mohs	—	Molybdenum (sintered), Ann.	B95	—
Thoria	7 Mohs	—	Pearlitic Malleable Irons	170	12
Mullite	6.5 Mohs	0.5	Carbon Steels (cast), Norm. & T.	170	7
Magnesia	6 Mohs	—	Cobalt (sintered)	170	—
Tungsten, CW	C53	14	Iridium, Ann.	170	—
Manganese-Silicon & Manganese-Nickel-Chromium-Molybdenum Steels, H & T (800 F)	450	63	Nickel Silvers, Extra Hard	B93	2
Nickel-Chromium-Molybdenum Steels (43xx), H & T (800 F)	440	5	Vanadium, CW	B93	—
Cast Stainless Steels, H & T	430	40	Zirconium, CW	B92	6
Nitrided Steels, H & T	410	—	Aluminum Bronzes (sand cast)	160	37
Duranickel, Age H	C41	5	Low Expansion Nickel Alloys, Ann.	160	13
Beryllium Coppers, CW & Ht Tr	C41	3	Iridium (cast)	160	—
Martensitic Stainless Steels, H & T	380	200	Yellow Brass, Hard	B90	—
Molybdenum Steels, H & T (300-1000 F)	380	150	Manganese Bronze, Half Hard	B90	—
Chromium-Vanadium Steels, H & T (300-1200 F)	380	66	Nickel Silvers, Hard	B88	3
High Carbon Steels, H & T (700 F)	350	40	Austenitic Stainless Steels, Ann.	150	5
Osmium (cast)	350	—	Phosphor Bronzes, Hard	B86	11
Iridium, CW	350	—	Low Carbon Steels, CW	140	25
Monel, Age H	C37	3	Ingot Iron, CD	140	—
Inconel (cast), Ann. & Aged	340	40	Low Brass, 80%, Hard	B82	—
Monel (cast), Ann. & Aged	340	40	Cartridge Brass, 70%, Hard	B82	—
Nickel-Chromium-Molybdenum Steels (86xx, 87xx), H & T (800 F)	330	89	Naval Brass, Half Hard	B82	—
Low Alloy Steels (cast), H & T	320	82	Vanadium, Ann.	B81	—
Rhodium, CW	320	65	Yellow Brass, Hard	B80	—
Inconel, Ann. & Age H	C33	4	Standard Malleable Irons	130	17
Titanium Alloys, Ann.	C32	6	Cobalt, Ann.	130	8
Nitriding Steels, H & T (1200 F)	290	32	Aluminum and Its Alloys, T6	130	—
Titanium, Ann.	C30	—	Hafnium, Ann.	B78	—
Monel, Ann. & Age H	C28	5	Red Brass, 85%, Hard	B77	—
Inconel (cast)	260	120	Muntz Metal, Half Hard	B75	—
High Carbon Steels (HR)	260	29	Low Carbon Steels (HR)	120	21
Molybdenum (sintered), CW	C24	3	Aluminum and Its Alloys, T4	120	15
Manganese Steels, H & T (300-1000 F)	250	34	Cobalt (cast)	120	15
Monel (cast)	240	110	Carbon Steels (cast), Ann.	120	—
Austenitic Stainless Steels, CW	240	—	Commercial Bronze, 90%, Hard	B70	—
Gray Irons	230	65	Calcia	4.5 Mohs	—
High Alloy Steels (cast), Aged 24 Hr at 1400 F	230	42	Austenitic Stainless Steels, Ann.	110	35
Nickel Steels, CD	230	29	Nickel (cast)	110	20
Nodular Irons	220	80	Aluminum and Its Alloys, T3	110	12
Ruthenium	220	—	Palladium, CW	110	—
			Zirconium, Ann.	B66	25
			Gilding, 95%, Hard	B64	—
			Nickel Silvers (sand cast)	100	50
			Rhodium, Ann.	100	50
			Wrought Iron (HR)	100	—

[a]Values are Rockwell when preceded by letter scale, and Mohs where indicated; all other values are Brinell.

Hardness of Metals and Ceramics—concluded

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
Tantalum, CW	E95	—	Nickel Silvers (sand cast)	H79	1
Aluminum and Its Alloys, T72	95	—	Platinum, Ann	45	7
Nickel, Ann	B59	5	Aluminum and Its Alloys, Ann	44	21
Beryllium Coppers, Ann	B57	8	Copper, Ann	F40	—
Zinc Alloys (die cast)	86	4	Zinc (HR)	42	5
Copper, Hard	B50	—	Silver (cast)	42	—
Ingot Iron (HR)	83	—	Aluminum and Its Alloys, H14	36	4
Aluminum and Its Alloys, H38	81	18	Gold (cast)	33	—
Magnesium (cast), Sol'n Tr	76	7	Silver, Ann	30	5
Muntz Metal, Ann	F80	—	Gold, Ann	25	—
Copper, Half Hard	B40	—	Pewter (cast)	23	—
Zinc Alloys (CR)	70	10	Tin-Base Babbitts (chill cast)	22	5
Aluminum Brass, Ann	F77	—	Lead-Base Babbitts (chill cast)	21	7
Admiralty Metal, Ann	F75	—	White Metal (cast)	20	—
Ingot Iron, Ann	69	—	White Metal, Ann	17	—
Magnesium Alloys (forged)	58	11	Pewter, Ann	13	—
Gold, CW	58	—	Hard Lead Alloys (chill cast)	11.2	4.2
Magnesium Alloys (cast), Sol'n Tr	57	6	Hard Lead Alloys (extr)	8.7	3.7
Zinc Alloys (HR)	56	5	Grade A Tin (CR)	8	—
Tantalum, Ann	E60	—	Hard Lead Alloys (rolled)	7.7	1.8
Platinum, CW	55	42	Grade A Tin, Ann	7	—
Magnesium Alloys (extr)	54	13	Tellurium Lead (extr)	6	—
Magnesium Alloys (cast)	49	16	Grade A Tin (as cast)	5.5	0.5
Aluminum and Its Alloys, H18	49	6	Soft Lead (chill cast)	4.2	—
Palladium, Ann	46	—			

Hardness of Plastics and Rubber[a]

Material ↓	Average	Range, ±	Material ↓	Average	Range, ±
ROCKWELL HARDNESS			Polyvinyl Chloride, Rigid	R118	2
			Nylon 66	R118	—
Urea	M118	2	Cellulose Acetate, Hard	R112	11
Melamines, Filled	M117	8	Polytrifluorochloroethylene	R112	3
Melamines, Unfilled	M117	3	Nylons 6 and 610	R111	7
Phenolics, GP	M114	6	Phenolics (cast), Transparent	R109	11
Plastics Laminates, GP	M110	10	Celiulose Nitrate Sheet	R105	10
Phenolics (cast), Mech & Cml	M106	14	Ethyl Cellulose	R95	25
Phenolics, Shock and Ht Res	M106	14	Cellulose Acetate, Medium	R93	22
Allyls (cast)	M105	13	Cellulose Acetate Butyrate	R86	28
Phenolics, Electrical	M105	5	Cellulose Acetate, Soft	R76	27
Diallyl Phthalate	M104	4	Cellulose Propionate	R70	50
Plastics Laminates, Electrical	M103	9	High Density Polyethylenes	R40	10
Phenolics (cast), Decorative	M97	8	Nylons, Soluble	R64	19
Plastics Laminates, Mech	M95	20			
Epoxies (cast)	M92	13	DUROMETER HARDNESS		
Acrylics	M91	12			
Polyesters (cast), Rigid	M90	25	Hard Rubber, High Ht Res	A88.5	3.5
Nylons, Glass Fiber-Filled	M90	5	Hard Rubber, Low Moisture Abs	A88	4
Silicone Plastics, GP	M89	—	Hard Rubber, Cml Res	A87	3
Polystyrene, Glass Fiber-Filled	M85	5	Hard Rubber, GP	A81.5	5.5
Mod Polystyrenes, Ht & Cml Res	M83	5	Polyvinyl-Chloride, Nonrigid	A75	25
Polyvinyl Formal	M85	—	Styrene-Butadiene Rubber	A65	25
Polymethylstyrenes	M79	4	Natural Rubber	A60	30
Polystyrenes, GP	M75	10	Polyvinyl Alcohol	A55	45
Rubber Phenolics	M65	25	Low Density Polyethylenes, Melt Index	<26 C73	—
Vinylidene Chloride	M57	8	Low Density Polyethylenes, Melt Index	200 D45	—
Modified Polystyrenes, High Impact	M55	25			
Silicone Plastics, High Impact	M45	—			

[a] In the first part of this table materials are listed in order of decreasing Rockwell hardness on two scales (M and R) which, though separated here, actually overlap to some indeterminate degree; in the second part of this table materials are listed in order of decreasing durometer hardness. No relationship between the two parts of the table is implied.

Creep Strength of Metals

Material ↓	Form, Condition	Stress (1000 psi) for 0.01% Creep per 1000 Hr at Indicated Temp (F)					Stress (1000 psi) for 0.1% Creep per 1000 Hr at Indicated Temp (F)				
Up to 800 F		300	400	500	600	800	300	400	500	600	800
NONFERROUS METALS											
Coppers	Wrought (annealed)	3–8	1.5–5	0.4–2.6	—	—	—	—	—	—	—
Nonleaded Brasses	Wrought (annealed)	0.9–19	2–11	0.3–23	—	—	25	5–9	1–2	—	—
Bronzes	Wrought (annealed)	14–23	5–10	2–5	—	—	—	—	—	—	—
Cupro-Nickel	Wrought (water quenched, aged)	25–40	15–30	8–30	—	—	—	22	13	—	—
Aluminum 2024-T	Sheet	52	44	—	—	—	—	—	—	—	—
Aluminum 7075-T	Sheet	50	30	—	—	—	—	—	—	—	—
Titanium (commercial)	Sheet (annealed)	—	38	—	32	10	—	—	—	—	—
Above 800 F		1000	1100	1200	1500	1600	1000	1100	1200	1500	1600
CARBON AND LOW ALLOY STEELS											
Low Carbon Steel	Wrought, Cast	1.8	—	0.1	—	—	3.3–5	—	0.5	—	—
Carbon-Molybdenum Steels	Wrought, Cast	5–7	3	1	—	—	10–12	4	2	—	—
Chromium-Molybdenum Steels (0.5–3%)	Wrought, Cast	6–12	2–4	1–2.5	—	—	10–20	3–8	2–4.5	—	—
Chromium Steels											
4–6%	Wrought, Cast	6–7	2.5–3.5	1–2	—	—	8–11	5–6.5	2–3.5	—	—
6–10%	Wrought, Cast	5–9	2.5–4	1–2	—	—	8–12	4–6	2.5–3	—	—
STAINLESS STEELS											
Martensitic Chromium Steels (403, 410, 416, 420)	Wrought	8	3.5	1.3	—	—	9.2	4.2	2	—	—
Ferritic Chromium Steels (405, 430, 440)	Wrought	4.2–7	2.3–4.5	1.0–1.6	—	—	6–8.5	3–5	1.5–2.2	—	—
Nickel-Chromium Steels											
304, 316, 321, 347	Wrought	12–17	7.5–11.5	4.5–7	1–2	—	17–25	12–18.2	7–12.7	1.2–2.8	—
309	Wrought	—	—	4	0.5	—	15.9	11.6	8	1.0	—
310, 314	Wrought	17	13	8	2	—	17	13–14	9	1–2.5	—
CORROSION RESISTANT CASTING ALLOYS											
Iron-Chromium Alloys (HC, HD)	Cast	—	—	—	—	—	—	—	—	1.2–3.5[a]	0.7–1.9
Iron-Chromium-Nickel Alloys (HE, HF, HH, HI, HK, HL)	Cast	—	—	—	—	—	—	—	—	3.5–7[a]	2–4.3
Nickel-Chromium Alloys (HT, HU, HW, HX)	Cast	—	—	—	—	—	—	—	—	6–8.5[a]	3–5
HIGH TEMPERATURE ALLOYS											
Inconel X		—	—	—	—	—	—	—	64	12.3	9.0
19-9 DL		—	—	—	—	—	—	—	20	7.1	—
Hastelloy X		—	—	—	—	—	—	—	—	—	2.4
N 155		—	—	—	—	—	—	—	18.4[b]	10.3	—
S-816		—	—	—	—	—	—	—	42	11.5	5.8

[a]At 1400 F. [b]At 1350 F.

Stress-Rupture Strength of Metals

Material ↓	Form, Condition	Stress (1000 psi) for Rupture in 100 Hr at Indicated Temp (F)					Stress (1000 psi) for Rupture in 1000 Hr at Indicated Temp (F)				
Up to 800 F		300	400	500	600	800	300	400	500	600	800
NONFERROUS METALS											
Coppers	Wrought (annealed)	22–25	20–24	—	—	—	19–21	15–19	—	—	—
Nonleaded Brasses	Wrought (annealed)	34–50	26–35	—	—	—	28–46	18–25	—	—	—
Bronzes	Wrought (annealed)	57	36	—	—	—	50	30	—	—	—
Aluminum Alloys											
2024–T	Sheet	—	—	—	—	—	37	19	—	—	—
7075–T	Sheet	—	—	—	—	—	20	9	—	—	—
Titanium (commercial)	Sheet (annealed)	—	45	—	—	20	—	44	—	32	16
Titanium Alloys											
4 Al–4 Mn		—	—	—	—	—	—	110	—	95	46
5 Al–2.5 Sn		—	—	—	—	—	—	76	—	65	58
8 Mn		—	—	—	—	—	—	100	—	91	26
Above 800 F		1000	1200	1400	1500	1600	1000	1200	1400	1500	1600
CARBON AND LOW ALLOY STEELS											
Low Carbon Steel	Wrought, Cast	15	5	1.5	—	—	10	2.8	0.7	—	—
Carbon–Molybdenum Steel (0.5% Mo)	Wrought	32–37	8	—	—	—	—	—	—	—	—
Chromium–Molybdenum Steels (0.5–3%)	Wrought	28–40	10–13	—	—	—	24–39	4–8	0.5–1.0	—	—
Chromium Steels											
4–6%	Wrought	23–30	4–9	2–3	1.5–2	—	18–20	5–7	1.8–2	0.7–1	—
6–10%	Wrought	—	10	3	2	—	—	6	2	1	—
STAINLESS STEELS											
Martensitic Chromium Steels (403, 410, 416, 420)	Wrought	—	—	—	—	—	13[a]	3[a]	—	—	—
Ferritic Chromium Steels (405, 430, 446)	Wrought	—	—	—	—	—	13[a]	3[a]	—	—	—
Nickel–Chromium Steels											
304, 316, 321, 347	Wrought	48–55	22–29	—	6–7	—	38–40	18–22	—	3.8–4.4	—
309	Wrought	—	28	—	8.5	—	—	20	—	4.8	—
310, 314	Wrought	38[a]	28	—	11	—	30	18	—	5	—
CORROSION RESISTANT CASTING ALLOYS											
Iron–Chromium Alloys (HC, HD)	Cast	—	—	3–10	—	1.5–5	—	—	2	—	1.2
Iron–Chromium–Nickel Alloys (HE, HF, HH, HI, HK, HL)	Cast	—	30–35	10–15	—	5–9	—	17–22	8–10	—	3.5–5
Nickel–Chromium Alloys (HT, HU, HW, HX)	Cast	—	—	10–18	—	6–8.5	—	—	7.5–12.5	—	4–7
HIGH TEMPERATURE ALLOYS											
Inconel X		115	80	42	30	11	110	55	33	18.5	6.6
19–9 DL		—	60	28	13	—	—	40	16.5	10.5	—
Hastelloy C		—	53	—	15	—	—	35	—	9.5	—
Hastelloy X		—	45	21	14	8	—	30	16	10	6
N–155		—	60	25.7	20	15	—	46	19.5	15	—
S–816		—	62	32	29	15	—	50	27	22	10
L605		—	45	30	22	15	—	—	23	18	11

[a] 10,000 hr.

Corrosion Resistance

Material ↓	Acetic Acid	Acetic Acid	Acetic Acid	Acetic Acid	Acetic Acid	Acetic Acid	Acetic Anhydride	Acetone	Alcohol	Alum	Aluminum Chloride	Aluminum Fluoride	Aluminum Sulfate	Ammonia (dry)	Ammonia (moist)	Ammonium Carbonate	Ammonium Chloride	Ammonium Chloride	Ammonium Chloride	Ammonium Fluoride	Ammonium Fluosilicate	Ammonium Nitrate
Conc, % / Temp, F	5 RT	25 RT	50 RT	50 BP	100 RT	100 BP	— RT	All AT	All AT	All BP	All BP	10 RT	All BP	— AT	— AT	50 BP	5 BP	25 BP	40 BP	10 RT	10 RT	All BP
Carbon Steel, Cast Iron	E	E	E	E	E	E	B	A	A	E	E	E	E	A	C	A	E	E	E	D	—	B[d]
14% Silicon Cast Iron	A	A	A	A	A	A	A	A	A	A	C	E	A	B	B	A	C	C	C	E	—	A
Stainless 304	A	A	A	D[b]	A	E[b]	A	A	A	E	E	E	D[b]	A	A	A	D[b,d]	E	E	C	—	A[e]
Stainless 316	A	A	A	A	A	A	A	A	A	E	E	E	C[b]	A	A	A	C[b,d]	E	E	A	—	A[e]
Stainless 20	A	A	A	A	A	A	A	A	A	C[b]	D[b,d]	D	C[b]	A	A	A	C[b,d]	E	E	A	—	A[e]
Aluminum	A	A	A	C	E[b]	E[b]	B	A	A	E	E	E	E	A	E	B	E	E	E	—	—	A
Copper	C[a]	C[a]	C[a]	C[a]	E	E	C	A	A	D[a]	E	D	A[a]	E	E	E	E	E	E	E	—	E
Red Brass	C[a]	C[a]	C[a]	C[a]	E	E	C	A	A	D[a]	E	D	A[a]	E	E	E	E	E	E	E	—	E
Cupro-Nickel	C[a]	C[a]	C[a]	C[a]	E	E	C	A	A	D[a]	E	D	A[a]	E	E	E	E	E	E	E	E[b]	E
Silicon Bronze	C[a]	C[a]	C[a]	C[a]	E	E	B	A	A	C[a]	E	D	A[a]	E	E	E	E	E	E	D	E[b]	E
Aluminum Bronze	C[a]	C[a]	C[a]	C[a]	E	E	B	A	A	C[a]	E	C	A[a]	E	E	E	E	E	E	D	—	E
Nickel	D	D	D	E	E	E	A	A	A	E	E	B	D	E	E	D	E	E	E	C	E[b]	C
Monel	C	C	C[a]	C[a]	E	E	A	A	A	C[a]	E	A	B	E	E	D	D	D	E	C	E[b]	E
Inconel	C	C	C	C	E	E	B	A	A	E	E	—	D	C	C	C	—	—	—	E	E	C
Hastelloy A	A	A	A	A	A	A	A	A	A	B	B	D[e]	C	A	A	A	B	B	B	—	—	—
Hastelloy B	A	A	A	A	A	A	A	A	A	A	A	D[e]	C	A	A	A	A	A	A	—	—	—
Hastelloy C	A	A	A	A	A	A	A	A	A	B	B	B[e]	A	A	A	A	B	B	B	—	B	B
Hastelloy D	A	A	A	A	A	A	A	A	A	A	E	D[e]	A	A	A	A	—	—	—	—	—	—
Hastelloy F	A	A	A	A	A	A	—	A	A	C[b]	E	—	A	A	A	A	A	A	—	—	—	—
Illium	A	A	A	A	A	A	—	A	A	C[b]	E	—	A	A	A	A	A	A	—	—	—	—
Stellite 6	A	A	A	A	A	A	A	A	A	—	D	—	A	—	—	—	D	D	—	—	—	—
Lead	E	E	E	E	E	E	—	A	A	A	E	C	A	A	A	—	—	—	—	D	—	E
Titanium	A	A	A	A	A	—	A	A	A	—	A	—	—	A	A	—	A	A	A	—	—	A
Silver	A	A	A	A	A	A	A	A	A	A	D	A	A	—	—	—	C	C	C	—	—	—
Impregnated Graphite	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	—	A
Vinylidene Chloride	A[c]	A[c]	A[c]	A[c]	A[c]	A[c]	A[c]	E	—	A[c]	A[c]	C[c]	A[c]	—	—	A[c]	A[c]	A[c]	A[c]	A[c]	—	—
Rubber	A[c]	A[c]	A[c]	A[c]	A[c]	A[c]	A[c]	E	—	A[c]	A[c]	C[c]	A[c]	A[c]	A[c]	A[c]	A[c]	A[c]	A[c]	A[c]	—	B
Glass, Stoneware	A	A	A	A	A	A	A	A	A	A	A	E	A	A	A	C	A	A	A	E	—	A
Tantalum	A	A	A	A	A	A	A	A	A	A	A	E	A	—	—	—	A	A	A	D	—	A
Platinum	A	A	A	A	A	A	A	A	A	A	A	A	A	—	—	—	A	A	A	A	—	—

[a]Solution must be air-free. Material is subject to excessive corrosion when solution is aerated with oxygen or air.
[b]Material may be subject to pitting corrosion when in contact with this corrosive.
[c]Material has rating indicated up to the limiting service temperature (150-180 F for rubber; 125-150 F for Saran).
[d]Material is subject to stress corrosion cracking when in contact with this corrosive.
[e] Material is subject to intergranular corrosion when in contact with this corrosive.

KEY TO RATINGS

A = Material is entirely suitable for the service indicated; the anticipated corrosion is almost negligible.
B = Material is suitable for the service indicated; corrosion is usually less than 1/2 in. penetration per year.
C = Material is acceptable for some services; corrosion is usually less than 1/16 in. penetration per year.
D = Acceptability of material is questionable; corrosion is usually excessive and material should not be used without prior corrosion testing under actual service conditions.
E = Material is not acceptable; corrosion is excessive.

Corrosion Resistance—continued

Material ↓	Ammonium Phosphate	Ammonium Sulfate	Ammonium Sulfate	Aniline	Arsenic Acid	Barium Carbonate	Barium Chloride	Barium Hydroxide	Barium Nitrate	Barium Sulfate	Benzene	Benzoic Acid	Boric Acid	Bromine (dry)	Bromine (wet)	Butyl Acetate	Butyric Acid	Calcium Bisulfite	Calcium Carbonate	Calcium Chloride	Calcium Hydroxide
Conc, %	10	5	10	—	—	All	10–20	50	10	—	Conc	—	All	—	—	Conc	All	10 SO_2	All	All	10
Temp, F	RT	RT	BP	IT	—	RT	IT	BP	RT	—	RT	—	AT	RT	RT	RT	AT	RT	BP	BP	BP
Carbon Steel, Cast Iron	D	D	E	E	E	A[d]	—	A[d]	C	C	A	E	D	D	E	B	D	E	B	C	B
14% Silicon Cast Iron	E	A	A	B	C	B	A	C	A	B	A	A	A	B	D	A	A	E	B	A	E
Stainless 304	B	E[b]	E[b]	B	C	A[d]	D[b,d]	A[d]	A	C	A	B	B	E	E	B	B	E	B	D[b,d]	B
Stainless 316	A	D[b]	E	B	B	A[d]	C[b,d]	A[d]	A	B	A	A	B	D	E	A	B	E	B	D[d]	B
Stainless 20	A	B	B	B	B	B	B[b]	A[d]	—	A	A	A	B	D	E	A	B	B	B	C	A
Aluminum	D	E	E	E[b]	—	E	E	E	—	—	A	B	D	E	E	A	B	B	E	E	E
Copper	E	E	E	E	D	C	—	E	E	C	A	B[a]	C[a]	C[a]	E	B	B[a]	B[a]	B	B	B
Red Brass	E	E	E	E	—	C	—	E	E	C	A	B[a]	C[a]	C[a]	E	B	B[a]	—	B	B	B
Cupro-Nickel	E	E	E	E	—	C	—	E	E	C	A	B[a]	C[a]	C[a]	E	B	B[a]	—	B	B	B
Silicon Bronze	E	D	E	E	D	B	—	E	E	B	A	B	C[a]	C[a]	E	B	B[a]	—	B	B	B
Aluminum Bronze	E	E	E	E	D	B	—	E	E	B	A	B	C[a]	C[a]	E	B	B[a]	—	B	B	B
Nickel	E	C	C	—	—	A	B	A	—	C	A	B	C	A	E	B	C[a]	E	A	A	A
Monel	C	B	C	—	—	A	B	A	—	B	A	B	C	A	E	B	C[a]	E	A	A	A
Inconel	—	C[b]	C[b]	—	—	—	B	A	C	C	A	B	C	A	E	B	C[a]	E	B	A	B
Hastelloy A	—	—	—	B	—	A	B	A	—	—	A	A	—	—	—	A	B	—	B	B	—
Hastelloy B	—	B	B	A	—	A	B	A	A	B	A	A	A	A	—	A	B	—	B	B	—
Hastelloy C	—	C	C	B	—	A	B	A	—	—	A	A	A	A	A	A	A	B	B	A	A
Hastelloy D	—	C	C	B	—	A	B	A	—	—	A	A	A	—	—	A	B	—	B	B	—
Hastelloy F	—	B	C	—	—	—	—	A	—	—	A	—	B	—	—	B	—	C	B	—	—
Illium	—	B	C	—	—	—	—	A	—	—	A	—	B	—	—	B	A	C	B	—	—
Stellite 6	—	—	—	—	—	—	—	—	—	—	A	—	—	—	—	A	—	—	—	—	—
Lead	C	A	A	B	D	E	—	E	—	—	A	E	B	C	A	A	E	B	B	D	E
Titanium	—	—	—	—	—	—	A	—	—	—	A	—	—	—	—	A	—	—	—	A	—
Silver	—	A	A	—	—	—	—	—	—	—	A	—	—	—	—	A	—	—	—	—	—
Impregnated Graphite	—	A	A	A	A	—	A	A	A	A	A	A	A	E	E	B	A	A	C	A	C
Vinylidene Chloride	—	A[c]	A[c]	—	—	—	—	—	—	A[c]	D[c]	—	A[c]	E	E	E	—	—	—	A[c]	—
Rubber	—	A[c]	A[c]	E	A[c]	A[c]	A[c]	A[c]	B[c]	A[c]	E	A[c]	A[c]	E	E	E	—	A	A[c]	A[c]	A[c]
Glass, Stoneware	—	A	A	A	B	B	A	A	A	A	A	A	A	A	A	A	A	A	C	A	E
Tantalum	—	—	—	A	—	—	A	—	A	—	A	—	A	A	A	A	—	—	—	—	—
Platinum	—	—	—	—	—	—	A	—	A	—	A	—	—	—	—	A	—	—	—	—	—

[a] Solution must be air-free. Material is subject to excessive corrosion when solution is aerated with oxygen or air.
[b] Material may be subject to pitting corrosion when in contact with this corrosive.
[c] Material has rating indicated up to the limiting service temperature (150-180 F for rubber; 125-150 F for Saran).
[d] Material is subject to stress corrosion cracking when in contact with this chemical.

KEY TO CONDITIONS

AT = All temperatures. BP = Boiling temperature. Conc = Concentrated.
RT = Room temperature. IT = Intermediate temperatures. All = All concentrations.

continued

Corrosion Resistance—continued

Material ↓	Calcium Hypochlorite	Carbon Dioxide (dry)	Carbon Dioxide (wet)	Carbon Bisulfide	Carbon Tetrachloride (dry)	Carbonic Acid	Chloracetic Acid	Chlorine (dry)	Chlorine (wet)	Chlorosulfonic Acid	Chromic Acid	Citric Acid	Copper Sulfate	Dowtherm	Ethers	Ethyl Acetate	Ethylene Dichloride	Ethylene Glycol	Fatty Acids	Fatty Acids	Fatty Acids	Ferric Chloride
Conc, %	Conc	All	—	Conc	—	10	All	—	—	All	—	All	All	—	—	—	—	—	—	—	—	25
Temp, F	RT	AT	—	RT	AT	RT	IT	—	—	RT	—	AT	BP	—	RT	RT	IT	IT	RT	350	500	RT
Carbon Steel, Cast Iron	E	A	D	C	C	C	E	B	E	E	C[d]	E	E	A	B	B	B	B	E	E	E	E
14% Silicon Cast Iron	B	A	A	B	A	A	B	A	B	B	B	A	A	—	B	B	B	B	A	A	A	D
Stainless 304	D[b]	A	B	C	C	B	E	C	E	D	C[b]	B	B	A	B	B	B	B	B	C	E	E[b]
Stainless 316	D[b]	A	A	B	B	B	E	C	E	D	C	A	B	A	B	B	B	A	B	B	B	E[b]
Stainless 20	D[b]	A	A	B	B	B	E	C	E	D	B	A	A	A	B	B	B	A	B	B	B	E[b]
Aluminum	E	A	—	—	D	B	E	D	E	E	D	C	E	—	B	B	B	B	B	C	E	E
Copper	E	A	B	B	A	B[a]	E	B[a]	E	—	E	B[a]	E	—	B	B	B	B	C	D	E	E
Red Brass	E	A	—	—	B	B[a]	E	B[a]	E	—	E	B[a]	E	—	B	B	B	B	C	D	E	E
Cupro–Nickel	E	A	B	B	A	B[a]	E	B[a]	E	—	E	B[a]	E	—	B	B	B	B	C	D	E	E
Silicon Bronze	D	A	B	B	B	B	D[a]	B	E	—	E	B[a]	E	—	B	B	B	B	C	D	E	E
Aluminum Bronze	E	A	B	B	A	B	E	B	E	—	E	B[a]	E	—	B	B	B	B	C	C	E	E
Nickel	E	A	—	B	B	D	C	B	E	C	E	B[a]	D	A	B	B	B	B	B	C[b]	E	E
Monel	E	A	—	B	B	C	C	B	E	B	D	B[a]	C	A	B	B	B	B	B	B	E	E
Inconel	E	A	B	—	B	B	C	A	E	B	B	B	D	—	B	B	B	B	B	B	B	E
Hastelloy A	—	A	—	—	B	—	—	—	—	—	—	A	—	—	B	B	B	B	A	A	A	—
Hastelloy B	—	A	A	—	A	A	A	—	—	A	—	A	—	—	B	B	B	B	A	A	A	E
Hastelloy C	B	A	A	—	A	A	B	A	B	B	B	A	A	—	B	B	B	B	A	A	A	B
Hastelloy D	—	A	—	—	B	—	B	—	—	B	—	A	—	—	B	B	B	B	A	A	A	E
Hastelloy F	—	A	—	—	—	—	—	—	—	B	—	A	—	—	B	B	B	B	A	A	B	—
Illium	B	A	B	—	A	B	—	E	E	B	D	A	B	—	B	B	B	B	A	A	B	E
Stellite 6	B	A	—	—	—	—	—	—	—	—	—	—	—	—	B	B	B	B	A	B	B	—
Lead	E	—	—	A	A	D	E	A	E	B	A	A	A	A	B	B	B	B	E	E	E	D
Titanium	A	—	—	—	A	—	—	E	A	A	A	B	—	—	B	B	A	—	—	—	—	A
Silver	—	—	A	—	A	A	A	A	A	—	—	B	B	—	A	A	A	—	A	A	A	—
Impregnated Graphite	A	—	—	—	A	A	A	A	A	A	D	A	A	A	B	B	B	A	A	A	A	A
Vinylidene Chloride	A	—	A	—	A	A	—	—	—	—	—	—	—	—	—	—	E	B	A	E	—	A
Rubber	A	—	A	—	E	A	A[c]	—	—	—	E	A	A	—	E	E	E	B	—	—	—	A
Glass, Stoneware	A	A	A	—	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Tantalum	B	—	A	—	A	A	A	A	A	—	A	A	B	—	A	A	A	—	—	—	—	B
Platinum	—	—	A	—	—	A	A	A	A	—	—	—	—	—	A	A	A	—	—	—	—	—

[a]Solution must be air-free. Material is subject to excessive corrosion when solution is aerated with oxygen or air.
[b]Material may be subject to pitting corrosion when in contact with this corrosive.
[c]Material has rating indicated up to the limiting service temperature (150-180 F for rubber; 125-150 F for Saran).
[d]Material is subject to stress corrosion cracking when in contact with this corrosive.

KEY TO RATINGS

A = Material is entirely suitable for the service indicated; the anticipated corrosion is almost negligible.
B = Material is suitable for the service indicated; corrosion is usually less than ½ in. penetration per year.
C = Material is acceptable for some services; corrosion is usually less than ⅛ in. penetration per year.
D = Acceptability of material is questionable; corrosion is usually excessive and material should not be used without prior corrosion testing under actual service conditions.
E = Material is not acceptable; corrosion is excessive.

Corrosion Resistance—continued

Material ↓	Ferric Sulfate	Ferrous Sulfate	Fluorine (dry)	Fluorine (wet)	Fluosilicic Acid	Formaldehyde	Formic Acid	Glycerine	Hydrobromic Acid	Hydrochloric Acid	Hydrofluoric Acid	Hydrogen	Hydrogen	Hydrogen Peroxide	Hydrogen Sulfide (dry)	Hydrogen Sulfide (wet)	Iodine (dry)	Iodine (wet)	Lactic Acid	Magnesium Chloride	Magnesium Sulfate
Conc, %	10	—	—	—	10	—	All	—	30	All	30	—	—	30	—	—	—	—	All	30	10
Temp, F	—	—	—	—	RT	—	BP	RT	RT	IT	IT	Cold	Hot	RT	RT	RT	RT	RT	180	RT	RT
Carbon Steel, Cast Iron	E	E	B	E	E	C[f]	E	B[f]	E	E	E	B	C	D	C[d]	D[d]	B	E	E	C	C
14% Silicon Cast Iron	C	B	E	E	E	A	A	A	B	B	E	B	—	C	B	B	B	E	B	C	A
Stainless 304	C[b]	C	C	E	E	B	B	B	E[b]	E	E[d]	B	B	B	B[b]	C[b]	B	E	C	C[d]	B
Stainless 316	C	B	B	E	D	B	B	A	E	E	D[d,g]	B	B	B	B[d]	C[d]	B	E	B	B[d]	B
Stainless 20	B	B	B	E	B	A	B	A	E	E	C[g]	B	B	B	B[d]	B[d]	B	—	B	B	B
Aluminum	E	—	B	E	E	B[b]	E	A	E	E	E	B	—	B	B	B	B	E	E	D	C
Copper	E	B[a]	C	E	B[a]	B	B[a]	A	E	E	B[a]	B	—	E	B	E	E	E	B	B[a]	B[a]
Red Brass	E	B[a]	C	E	C[a]	B	B[a]	A	E	E	B[a,d]	B	—	E	B	E	B[a]	E	C	B[a]	B
Cupro-Nickel	E	B[a]	A	B	B[a]	B	B[a]	A	E	E	B[a,d]	B	—	E	B	E	B[a]	E	C	B[a]	B
Silicon Bronze	E	B[a]	—	—	B[a]	B	B[a]	A	C	C[a]	B[a]	B	—	E	B	E	B	E	C	B[a]	B
Aluminum Bronze	E	B[a]	—	—	B[a]	B	B[a]	A	—	E	B[a]	B	—	E	B	E	B	E	B	B[a]	B
Nickel	E	E	B	—	C	B[f]	B[a]	A	C	D[a]	C[a]	B	B	—	B	E	E	E	C[a]	A	B
Monel	E	C	A	A	B[d]	B	B[a]	A	—	E	B[a,d]	B	—	—	B	E	B	E	D	B	B
Inconel	E	E	B	—	B	A	—	B	E	E	E	B	B	—	B	B	E	E	B	A	B
Hastelloy A	E	B	B	—	B	B	—	A	—	—	—	B	B	—	B	B	—	—	—	A	A
Hastelloy B	E	B	B	B	B	B	—	A	B	B	—	B	B	—	B	B	—	—	B	A	A
Hastelloy C	A	B	B	C	B	B	A	A	—	—	B	B	B	B	B	B	B	B	B	A	A
Hastelloy D	—	B	B	—	B	B	—	A	—	—	—	—	—	—	B	B	—	—	B	A	A
Hastelloy F	—	—	B	—	—	A	—	B	—	—	—	B	B	—	E	E	—	—	B	A	B
Illium	C	B	B	—	—	A	A	B	—	—	—	B	B	—	E	E	E	E	B	A	B
Stellite 6	—	—	—	—	—	—	—	—	—	—	—	B	B	—	—	—	—	—	—	—	—
Lead	B	B	B	—	—	E	E	B	E	E	B[a]	B	—	E	B	—	E	E	E	E	B
Titanium	—	—	—	—	—	A	C	—	—	—	E	—	—	A	A	A	—	—	A	A	—
Silver	—	—	A	A	—	—	—	—	—	B	B	A	—	—	—	—	—	—	—	—	—
Impregnated Graphite	—	A	E	—	A	A	A	—	A	A	A	A	—	—	—	—	E	E	B	A	B
Vinylidene Chloride	A	A	—	—	A	A	A	—	—	A	—	A	—	A	—	—	—	—	—	A	B
Rubber	A	A	E	—	A	A	A	A	A	A	B	C	—	E	—	—	A	—	A	A	A
Glass, Stoneware	A	A	E	—	E	A	A	A	A	A	E	A	—	A	A	A	—	—	A	A	A
Tantalum	A	A	—	—	—	—	A	—	A	A	B	A	A	A	—	—	B	B	—	B	—
Platinum	—	—	A	A	—	—	—	—	—	A	—	A	A	—	—	—	—	—	—	—	—

[a] Solution must be air-free. Material is subject to excessive corrosion when solution is aerated with oxygen or air.
[b] Material may be subject to pitting corrosion when in contact with this corrosive.
[d] Material is subject to stress corrosion cracking when in contact with this chemical.
[f] Material may discolor the chemical.
[g] Material meets this rating only when corrosive is aerated with oxygen or air.

KEY TO CONDITIONS

AT = All temperatures. BP = Boiling temperature. Conc = Concentrated.
RT = Room temperature. IT = Intermediate temperatures. All = All concentrations.

continued

Corrosion Resistance—continued

Material ↓	Mercuric Chloride	Mercury	Nickel Chloride	Nickel Sulfate	Nitric Acid	Nitric Acid	Oxalic Acid	Oxygen	Oxygen	Phenol	Phosphoric Acid	Phosphoric Acid	Potassium Chloride	Potassium Hydroxide	Potassium Sulfate	Sodium Acetate	Sodium Bisulfate	Sodium Carbonate	Sodium Chloride	Sodium Hydroxide	Sodium Hydroxide	Sodium Hydroxide
Conc, %	10	—	—	10	30	50	All	—	—	All	10	85	10–20	30–50	10	—	—	—	—	30	50	50
Temp, F	RT	—	—	150	BP	BP	AT	<1000	>1000	AT	212	RT	100	150	RT	—	—	—	—	140	150	BP
Carbon Steel, Cast Iron	E	B	E	E	E	E	E	A	—	C[f]	E	E	C	B[d]	C	C	E	B	B	A	B[d]	B[d]
14% Silicon Cast Iron	B	—	B	B	A	A	B	A	—	A	C	C	B	E	B	—	B	B	B	E	E	E
Stainless 304	E	B	E	D	B[e]	B[e]	B	A	A	B	B[e]	B[e]	B[b]	B[d]	B	B[b]	B	B	B[b]	A	B[d]	B[d]
Stainless 316	E	—	E	B	B[e]	B[e]	A	A	A	B	B[e]	B[e]	B[b]	B[d]	B	B	B	B	B	A	B[d]	B[d]
Stainless 20	E	—	E	A	C[e]	C[e]	A	A	A	B	B[e]	B[e]	B	B[d]	B	B	B	B	B	—	—	—
Aluminum	E	E	E	E	E	E	E	A	—	B	E	E	E	E	B	B	E	E	D[b]	E	E	E
Copper	E	E	E	B[a]	E	E	B[a]	A	—	C	B[a]	B[a]	B	C	B	B	B[a]	B	B	B	B	E
Red Brass	E	E	E	B[a]	E	E	—	A	—	C	B[a]	B[a]	B	—	B	B	B[a]	B	B	B	C	E
Cupro–Nickel	E	E	E	B[a]	E	E	B[a]	A	—	C	B[a]	B[a]	B	B	B	B	B[a]	B	B	B	B	C
Silicon Bronze	E	E	E	B[a]	E	E	B	A	—	B	B[a]	B[a]	B	C	B	B	B[a]	B	B	B	E	E
Aluminum Bronze	E	E	E	B[a]	E	E	B[a]	A	—	B	B[a]	B[a]	B	C	B	B	B[a]	B	B	B	B	E
Nickel	C	B[d]	E	B[b]	E	E	C	A	A	B	C[a]	C[a]	A	A	B	—	—	B	B	A	A	A[d]
Monel	E	B[d]	B[a]	B[a]	E	E	B	A	—	B	B[a]	B[a]	A	A	A	C	—	B	B	A	A	A[d]
Inconel	E	B	E	B[a]	E	E	A	A	A	B	B	B	A[b]	B	B	—	—	B	B	A	A	A[d]
Hastelloy A	—	B	A	—	—	—	B	A	A	B	—	—	—	B	—	B	—	B	B	—	—	—
Hastelloy B	—	B	A	—	—	—	B	A	A	B	B	B	B	B	B	B	B	B	B	A	A	A
Hastelloy C	B	B	—	B	C	E	B	A	A	B	—	—	B	B	—	B	—	B	B	—	—	—
Hastelloy D	—	B	—	—	—	—	B	A	A	B	—	—	—	B	—	B	—	B	B	—	—	—
Hastelloy F	—	B	—	—	E	E	B	A	A	B	B	B	B	B	B	—	—	B	—	A	A	A
Illium	—	B	—	B[a]	E	E	B	A	A	B	B	B	B	B	B	—	—	B	E	A	A	A
Stellite 6	—	—	—	—	B	B	B	A	A	B	—	—	—	—	—	—	—	—	—	B	B	B
Lead	C	E	—	B	E	E	E	—	—	C	B	B	E	E	B	—	B	E	B	E	E	E
Titanium	A	—	A	—	B	B	C	A	—	—	B	B	B	B	—	—	—	—	A	B	B	—
Silver	—	—	—	—	E	E	—	A	A	B	B	B	—	—	—	—	—	—	—	—	—	—
Impregnated Graphite	A	—	A	A	C	E	A	—	—	A	A	A	A	B	B	A	A	A	A	C	D	—
Vinylidene Chloride	A	—	A	—	—	—	—	—	—	A	A	A	—	—	—	—	—	—	A	A	A	—
Rubber	A	—	A	A	E	E	A[c]	—	—	A[c]	A	A	A	A	B	—	A	A	A	A	A	—
Glass, Stoneware	A	B	A	A	A	A	A	—	—	A	A	A	A	E	B	A	A	A	A	E	E	E
Tantalum	—	—	—	—	A	A	A	A	—	B	—	—	—	—	—	—	—	A	A	—	—	—
Platinum	—	—	—	—	A	A	—	A	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[a]Solution must be air-free. Material is subject to excessive corrosion when solution is aerated with oxygen or air.
[b]Material may be subject to pitting corrosion when in contact with this corrosive.
[c]Material has rating indicated up to the limiting service temperature (150-180 F for rubber; 125-150 F for Saran).
[d]Material is subject to stress corrosion cracking when in contact with this chemical.
[e]Material is subject to intergranular corrosion when in contact with this corrosive. [f]Material may discolor the chemical.

KEY TO RATINGS

A = Material is entirely suitable for the service indicated; the anticipated corrosion is almost negligible.
B = Material is suitable for the service indicated; corrosion is usually less than 1/2 in. penetration per year.
C = Material is acceptable for some services; corrosion is usually less than 1/16 in. penetration per year.
D = Acceptability of material is questionable; corrosion is usually excessive and material should not be used without prior corrosion testing under actual service conditions. E = Material is not acceptable; corrosion is excessive.

Corrosion Resistance—concluded

Material ↓	Sodium Hypochlorite	Sodium Nitrate	Sodium Phosphate	Sodium Sulfate	Sodium Sulfite	Sulfite Liquors	Sulfur	Sulfur	Sulfur	Sulfur Dioxide (dry)	Sulfur Dioxide (wet)	Sulfuric Acid	Sulfuric Acid	Sulfuric Acid	Sulfuric Acid	Sulfurous Acid	Tall Oil	Tannic Acid	Trichloroethylene	Vinyl Chloride	Zinc Chloride
Conc, %	—	30	10	20	10	—	Molten	—	—	—	—	10	20–50	50–70	70–100	—	—	10	—	—	—
Temp, F	—	RT	RT	RT	RT	—	260	500	830	—	—	RT	RT	RT	RT	RT	—	150	—	—	—
Carbon Steel, Cast Iron	E	B[d]	B	C	E	C[b]	B	B	B	B	E	E	E	E	B	D	E	E	C[h]	C[f,h]	B[h]
14% Silicon Cast Iron	B	A	B	A	E	E	—	—	—	E	E	E	B	A	A	E	B	B	B	—	B
Stainless 304	D[b]	A	B	B	B	C[b]	B[b]	B[b]	B[b]	B	E	E	E	E	E	E	C	B	B[b]	B[d]	B[d,h]
Stainless 316	C[b]	B	B	B	B	B	B	B	B	B	B	—	—	—	—	C	B	B	B	B	B[d,h]
Stainless 20	C	B	B	B	B	—	B	B	B	B	B	B	B	B	B	B	A	B	B	B	B[d]
Aluminum	E	B	E	A	—	E	B	B	B	B	B	E	E	E	E	B	E	C	B[b]	E	B[h]
Copper	E	C	B	B	B	—	E	E	E	B	E	C[a]	C[a]	E	E	C	D	B[a]	B	E	E
Red Brass	E	C	B	A	B	—	E	E	E	B	E	C[a]	C[a]	E	E	C	E	—	B	E	E
Cupro-Nickel	E	C	B	B	B	—	E	E	E	B	E	C[a]	C[a]	E	E	C	—	—	B	E	E
Silicon Bronze	C	C	B	B	B	—	C	E	E	B	E	B[a]	C[a]	E	E	C	—	B	B	E	E
Aluminum Bronze	E	C	B	B	B	—	E	E	E	B	E	B[a]	C[a]	E	E	C	—	—	B	E	E
Nickel	E	B	B	A	—	—	B[a]	C[a]	E	B	E	E	E	E	E	D	B	—	A	—	B
Monel	E	B	B	A	B	—	B[a]	C[a]	E	B	E	B[a]	B[a]	E	E	E	B	B	A	—	B
Inconel	E	B	—	A	—	B	B[a]	B[a]	B[a]	B	E	E	E	E	E	D	B	—	A	—	C
Hastelloy A	—	—	—	B	—	—	B[g]	B[g]	—	—	—	—	—	—	—	—	—	—	A	—	—
Hastelloy B	—	—	—	B	—	—	B[g]	B[g]	—	—	—	A	A	B	B	—	—	—	A	—	B
Hastelloy C	B	B	—	B	B	B	B	B	B	B	B	—	—	—	—	B	A	B	A	—	—
Hastelloy D	—	—	—	B	—	—	—	—	—	—	—	A	A	B	B	B	—	—	—	—	—
Hastelloy F	—	—	—	—	—	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Illium	E	A	—	—	—	—	A	—	—	—	—	A	B	B	B	—	—	—	—	—	B
Stellite 6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lead	E	E	—	B	B	B	E	E	E	B	B	A	A	A	B	B	—	E	E	E	C
Titanium	A	A	—	—	—	—	A	—	—	—	—	B	D	E	E	—	—	A	A	A	A
Impregnated Graphite	E	A	—	A	A	—	—	—	—	A	A	A	A	B	E	A	—	B	A	—	A
Vinylidene Chloride	B	—	—	A	—	—	—	—	—	—	—	—	—	—	—	A	—	—	D	—	A
Rubber	A	B	A	A	A	—	E	E	E	E	E	A	A	E	E	A	—	A	E	E	A
Glass, Stoneware	A	A	A	A	E	E	—	—	—	A	A	A	A	A	A	A	A	A	E	A	A
Tantalum	A	A	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Platinum	—	—	—	—	—	—	—	—	—	—	—	B	B	B	B	—	—	—	—	—	—

[a] Solution must be air-free. Material is subject to excessive corrosion when solution is aerated with oxygen or air.
[b] Material may be subject to pitting corrosion when in contact with this corrosive.
[d] Material is subject to stress corrosion cracking when in contact with this chemical.
[f] Material may discolor the chemical.
[g] Material meets this rating only when corrosive is aerated with oxygen or air.
[h] Material has this rating only when corrosive is dry. Traces of moisture may make material unsuitable.

KEY TO CONDITIONS

AT = All temperatures. BP = Boiling temperature. Conc = Concentrated.
RT = Room temperature. IT = Intermediate temperatures. All = All concentrations.

Effect of Radiation on Metals

EFFECT ON HARDNESS

Material			Radiation Exposure[a]	Change in Brinell Hardness
Type	Condition	Initial Brinell Hardness		
CARBON STEELS				
1018	Annealed	174	1	+9
		156		+12
	Hardened	241	1	+6
	Annealed	138	2	+23
	Hardened	237		+6
1042	Annealed	201	1	+6
		236		+34
	Hardened	430	1	+14
	Annealed	225	2	−38[b]
	Hardened	390		+36
1045	Annealed	187	3	0
	Hardened	514		−144[c]
1095	Annealed	297	1	+14
	Hardened	542		+8
	Annealed	290	2	+25
	Hardened	535		0
1113	Annealed	195	1	+22
	Hardened	190		+5
1141	Annealed	220	1	+35
	Hardened	421		+9
STAINLESS STEELS				
304	Annealed	131	4	0
	Malcomized	654	5	+156
309	Annealed	152	4	+6
316	Annealed	143	4	0
	Annealed	154	5	+74
	Cold Worked	226		+59
329	Annealed	158	6	0
347	Annealed	152	4	0
	Annealed	183	6	0
	Malcomized	656	7	0
347 (Cb+Ta)	Annealed	153	6	+22
	Shot Peened	153		+15
410	Malcomized	656	5	+84
		688	7	0
		739	8	0
431	Annealed	277	6	+54
	Hardened	371		+29
440C	Hardened	545	5	0
		461	8	+73
		388		+27
	Malcomized	577	7	+223
442	Annealed	185	6	+38
	Hardened	200		+50
17-4PH	Annealed	315	6	+162
	Hardened	415	6	+35
		403	9	+29
		477		0
	Malcomized	740	6	+80
NICKEL AND ITS ALLOYS				
Nickel A	Annealed	64	10	+73
Hastelloy C	Cast	228	11	+132
		170		+58
	Wrought	255	10	+30
		209	12	0
		256	13	+19
Monel	Annealed	150	12	+59
		157	13	+23
K Monel	As Received	260	12	+25
		255	13	+10
	Annealed	148	6	+32
	Hardened	341		0
Inconel	As Received	175	12	+65
		180	13	+48
Inconel X	Annealed	209	12	+56
		219	13	+28

[a] 1 = nvt (integrated thermal flux-product of flux and exposure time) of 1 x 10^{19} slow at 450-500 F.
2 = nvt of 2 x 10^{19} slow and 7 x 10^{18} fast at 70-140 F.
3 = nvt of 3 x 10^{20} slow and 1 x 10^{20} fast at 70-80 F.
4 = nvt of 1.2 x 10^{19} slow in 400-500 F flowing water.
5 = nvt of 3.7 x 10^{20} slow and 5.1 x 10^{20} fast at 70-80 F.
6 = nvt of 3 x 10^{19} slow in 540 F flowing water.
7 = nvt of 10^{19} slow; dry exposure.
8 = nvt of 5 x 10^{19} slow and 4 x 10^{19} fast.
9 = nvt of 4.4 x 10^{19} slow in 540 F flowing water.
10 = nvt of 1 x 10^{19} slow in 400-500 F flowing water.
11 = nvt of 4 x 10^{19} slow and 5 x 10^{19} fast.
12 = nvt of 5 x 10^{19} slow and 4 x 10^{19} fast at 70-140 F.
13 = nvt of 4 x 10^{19} slow in 540 F flowing water.

[b] No explanation for decrease in hardness values.

[c] Decrease in hardness due to corrosion products caused by leaking container.

EFFECT ON TENSILE PROPERTIES

Material				Radiation Exposure[a]	Chg in Properties After Irradiation	
Type	Condition	Ten Str, 1000 psi	Elong (2 in.), %		Ten Str, 1000 psi	Elong, %
STAINLESS STEELS						
304	Annealed [b]	92	71	1	+1	−21
309	Annealed [b]	95	54	1	+4	−3
316	Annealed [b]	90	70	1	−1	−3
347	Annealed [b]	99	56	1	+4	−2
316	Annealed [c]	79	—	2	+71	—
410	Malcomized [c]	69	—	3	+3	—
440C	Hardened [c]	205	—	3	+35	—
NICKEL AND ITS ALLOYS						
Nickel	Wrought [b]	65	45	1	+4	−11
Monel	As Received	129 [d]	—	4	+4	—
		86 [e]	32		+5	−3
		85 [c]	33	5	+11	−23
K Monel	As Received	210 [d]	—	4	−15	—
		125 [e]	10		+8	+9
		211 [d]	—	5	+15	—
		123 [e]	11		+11	−8
Inconel	As Received	150 [d]	—	4	+10	—
		107 [e]	30		+6	−1
		151 [d]	—	5	+21	—
		106 [e]	31		+10	−2
Inconel X	As Received	174 [d]	—	4	+24	—
		128 [e]	36		+11	−1
		174 [d]	—	5	+29	—
		126 [e]	37		+7	−14
	Cast	80 [c]	—	3	+27	—
Hastelloy C	Wrought	139 [b]	53	1	+3	−11
		198 [d]	—	4	−7	—
		140 [e]	20	4	−3	+16
		138 [c]	20	5	+4	−8
		198 [d]	—		+22	—
HIGH DENSITY MATERIALS						
Tantalloy	As Received	136	29	6	+29	−15
Tungsten		152	0	6	−35	0
Tantalum		68	21	6	+18	−4
Tantung G		72	5	6	−3	−1

[a]1 = nvt of 1 x 10^{19} slow in 400-500 F flowing water.
2 = nvt of 3.7 x 10^{20} slow and 5.1 x 10^{20} fast at 70-80 F.
3 = nvt of 4 x 10^{19} fast.
4 = nvt of 4 x 10^{19} slow in 540 F flowing water.
5 = nvt of 5 x 10^{19} slow and 4 x 10^{19} fast in cooling water at 70-140 F.
6 = nvt of 1 x 10^{19} slow and 5 x 10^{19} fast (estimated).
[b]Flat specimens. [c]Subsize round specimens. [d]Notched specimens.
[e]Unnotched specimens.

EFFECT ON DENSITY[a]

Material		Avg Chg in Density After Irradiation, %
Type	Initial Density, lb/in.	
Stainless Steels		
316	7.995	−0.06
347	7.938	−0.09
347+Ta	7.942	−0.04
410	7.675	−0.05
Nickel A	8.894	−0.07
Monel	8.836	−0.05
Cobalt Alloys		
Stellite 3	8.550	+0.06
Stellite 6	8.330	+0.11
Carbon Steel (SA-212)	7.850	0

[a]Radiation exposure: nvt of 2 x 10^{20} slow and 3.5 x 10^{19} fast at 70-140 F.

EFFECT ON ELECTRICAL RESISTIVITY

Material		Avg Chg in Elec Res After Irradiation
Type	Initial Elec Res	
Stainless Steels		
304	80 (28.0 C)	+0.2 (27.8 C)
309	79 (27.5 C)	−2.1 (27.0 C)
316	77 (28.4 C)	+1.01 (28.4 C)
347	75 (26.2 C)	+0.44 (27.3 C)
Nickel A	9 (27.0 C)	−0.17 (27.2 C)
Hastelloy C	126 (26.2 C)	+7.30 (27.8 C)

Some Notes on the Data Section

What the Data Mean: With the exception of Section 7, the Properties of Materials sections consist entirely of tabular data on the properties, forms and uses of engineering materials.

Tabular data on properties generally represent average values or ranges obtained from many different sources and suppliers. A range of values may indicate either the normal variation encountered in that particular test, or the differences attributable to variations in the composition, temper, heat treatment, form or other condition of the material. Where a value or range applies only to a particular condition of the material, the condition is stated. Unless otherwise indicated, properties of metals apply to wrought forms and properties of nonmetallics apply to molded forms.

Available forms listed in these sections are the most important forms that are readily available commercially. Uses listed in these sections are only typical and are not intended to be exhaustive.

These data have a limited purpose. Space does not permit a complete description of the materials and test conditions to which the data apply; hence, these data cannot be used directly for final designs. They are intended solely to aid in the important job of materials selection.

Sources of the Data: Many of these compilations are entirely new. Others have been published previously in this magazine, particularly as File Facts. Most of the older compilations have been revised to a greater or lesser extent.

Collecting new data and up-dating old compilations required the aid of several hundred individuals and organizations. We gratefully acknowledge their assistance. Although it would be impractical to list all who contributed in one way or another, we acknowledge particularly the assistance of the following:

Acme Resin Corp.
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American Die Casting Inst.
American Foundrymen's Assn.
American Hard Rubber Co.
American Iron & Steel Inst.
American Lava Corp.
American Magnesium Corp.
American Metal Co., Ltd.
American Smelting & Refining Co.
American Society for Testing Materials
American Welding Society
American Zinc Inst.
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Catalin Corp. of America
Celanese Corp. of America
Ciba Co., Inc., Plastics Div.
Cincinnati Milling Machine Co.
Copper & Brass Research Assn.
Corning Glass Works
Crest Chemical Industries
D & R Pilot Plants, Inc
Dayton Rubber Co.
De Bell & Richardson, Inc.
Dow Chemical Co., Magnesium Div.
Dow Chemical Co., Plastics Dept.
Dow Corning Corp.
Drop Forging Assn.
du Pont de Nemours, E. I. & Co., Elastomer Chemicals Dept.
du Pont de Nemours, E. I. & Co., Electrochemicals Dept.
du Pont de Nemours, E. I. & Co., Polychemicals Dept.
East Coast Aeronautics, Inc.
Eastman Kodak Co., Eastman Chemical Products, Inc.
Electrochemical Society
Emerson & Cuming, Inc.
Enjay Co., Inc.
Eutectic Welding Alloys Corp.
Fansteel Metallurgical Corp.
Felt Assn.
Firestone Plastics Co., Chemical Sales Div.
Formed Steel Tube Inst.
General Electric Co., Chemical Materials Dept.
General Electric Co., Plastics Dept.
General Electric Co., Silicone Products Dept.
General Tire & Rubber Co.
Glastic Corp.
Globe-Union, Inc., Centralab Div.
Goodrich, B. F. Chemical Co.
Goodyear Tire & Rubber Co., Chemicals Div.
Goshen Rubber Co., Inc.
Grace, W. R. & Co., Polymer Chemicals Div.
Gray Iron Founders' Society
Greer Industries, Inc.
Hanson-Van Winkle-Munning Co.
Harshaw Chemical Co.
Hercules Powder Co., Cellulose Products Dept.
Hooker Electrochemical Co., Durez Plastics Div.
Hydropress, Inc.
International Nickel Co.
Investment Casting Inst.
Kaiser Aluminum & Chemical Corp.
Koppers Co., Inc., Chemical Div.
Landau, J. Co.
Latrobe Steel Co.
Lead Industries Assn.
Lincoln Electric Co.
Magnesium Assn.
Malleable Founders Society
Mallory-Sharon Titanium Corp.
Manufacturing Chemists' Assn.
Martin Co.
McDanel Refractory Porcelain Co.
McPherson, John L.
Meehanite Metal Corp.
Metal Powder Assn.
Metal & Thermit Corp.
Minnesota Mining & Mfg. Corp.
Mobay Chemical Co.
Monarch Machine Tool Co.
Monsanto Chemical Co., Plastics Div.
National Carbon Co.
National Screw Machine Products Assn.
New Jersey Zinc Co.
Ney, J. M. Co.
Nopco Chemical Co., Plastics Div.
Oak Ridge National Laboratories
National Paint, Varnish & Lacquer Assn.
Pelron Corp.
Penn Precision Products, Inc.
Phillips Petroleum Co.
Phillips Chemical Co., Rubber Chemicals Div.
Polymer Corp., Ltd.
Porcelain Enamel Inst.
Reichhold Chemicals, Inc.
Rem-Cru Titanium, Inc.
Republic Steel Corp.
Resistoflex Corp.
Reynolds Metals Co.
Rezolin, Inc.
Richardson Co.
Rolled Alloys, Inc.
Rubber Manufacturers' Assn.
Sisman, O.
Society of Automotive Engineers
Society of the Plastics Industry
Spencer Chemical Co.
Spincraft, Inc.
Star Porcelain Co.
Steel Founders' Society of America
Strux Corp.
Thiokol Chemical Corp.
Tin Research Inst., Inc.
Titanium Metals Corp. of America
Union Carbide Corp., Bakelite Co.
Union Carbide Corp., National Carbon Div.
Union Carbide Corp., Silicones Div.
U.S. Ceramic Tile Co., Diamonite Products Div.
U.S. Dept. of Agriculture
U.S. Graphite Co.
U.S. Industrial Chemicals Co.
U.S. Rubber Co., Naugatuck Chemical Div.
Van der Horst Corp.
Welding Research Council
Westinghouse Electric Corp.

Corrections and additions: In compiling a data section of this nature it is impossible to avoid errors. Also, space and time limitations prohibited us from making this section as complete as we wish to make it. We will welcome your corrections and additions for future editions. Please address them to Data Editor, MATERIALS IN DESIGN ENGINEERING, *430 Park Ave., New York 22, N. Y.*

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PAGE 223
6 Nonmetallics

FINISHES AND COATINGS
PAGE 247
7 Finishes & Coatings

SUPPLIERS' LITERATURE

Irons and Steels

Pearlitic Malleable Iron. Albion Malleable Iron Co., 23 pp, illus. Information on metallurgical characteristics of pearlitic malleable. (1)

Leaded Steel. Alco Products, Inc., illus., 8 pp. Facts about leaded steel for seamless forged and rolled rings. Physical property data on 11 grades and section sizes of Alco Hi-Qua-Led steel are included. (2)

Stainless Steel Strip. Allegheny Ludlum Steel Corp., 32 pp, illus. Contains more than 20 tables listing data on types of stainless steel strip and sheet, corrosion resistance, fabrication properties and weights. Discusses applications in the automotive, food processing, dairy and textile industries. (3)

Prefinished Metals. American Nickeloid Co., 24 pp, illus. Describes fabrication, uses and properties of prefinished metals. (4)

Stainless Steel. Armco Steel Corp., 24 pp, illus. Describes 45 types of stainless steel bar and wire, including several special proprietary grades. Information on advantages, properties, fabrication, electropolishing and ebonizing. (5)

Spring Steels. Associated Spring Corp., 48 pp, illus. Characteristics and uses of spring steels, types available, and specifications. Charts correlate thickness and tensile strength for three ranges of hardness. (6)

Low Alloy Steel. Bethlehem Steel Co., 66 pp, illus., No. 353. Properties of Mayari-R steel, used in applications requiring high strength and good wear and corrosion resistance. (7)

Bar Steels. Bliss & Laughlin, Inc., 4 pp, illus., No. 55. How Strain-Tempered bar steels improve products and reduce costs. Typical applications: shift spur gears and main drive splines. (8)

Tool, Die Steels. Cannon-Muskegon, Inc., 13 pp, Rev. No. 27. Technical data sheets give compositions of tool and die steels; physical property, forging and heat treating data on various tool steels; and information on a group of shock resisting, hot work, high speed and special purpose steels. Standard designations included. (9)

Stainless Steels. Carpenter Steel Co. A pocket-size chart on machining stainless steels. Gives data on turning, drilling, tapping, threading, milling and reaming operations. Also shows relative workability of stainless steels in deep drawing and stamping operations. (10)

Lead Treated Steel. Copperweld Steel Co., Steel Div., 8 pp, illus. Mechanical properties and applications of lead treated steels. (11)

Stainless Steel. Crucible Steel Co. of America, 16 pp, illus. Annealing, hardening and tempering temperatures and representative physical properties for austenitic, ferritic and martensitic stainless steels. Also discusses pickling and scale removal. (12)

Stainless Steel. Electric Steel Foundry Co., 12 pp, illus., No. 5. Mechanical properties of cast and wrought stainless steels after precipitation hardening heat treatments at temperatures from 800 to 1200 F. (13)

High Strength Steels. International Nickel Co., Inc., 29 pp, illus. How strength levels of 4340 nickel-chromium-molybdenum alloy steel can be increased. Test results show effects of lower tempering temperatures and other variations. (14)

Steelmaking. Jones & Laughlin Steel Corp., Stainless Steel Div., 12 pp, illus. Color photographs illustrate the various steps in the steelmaking process. (15)

Precipitation Hardening Steels. Latrobe Steel Co., 6 pp, illus. Properties of Cascade precipitation hardening die steel for plastics molds, zinc die casting dies and holding blocks. (17)

Steel Strip. Weirton Steel Co., Div. of National Steel Corp., 12 pp, illus. Characteristics of electrolytic zinc coated sheet and strip. How this material can be used for both decorative and functional applications. (18)

Precoated Strip. Thomas Strip Div., Pittsburgh Steel Co., 18 pp, illus. Discusses strip steel coated with zinc, copper, brass, lead alloy, nickel or chromium, with or without rolled-in patterns. (19)

Tool Steel. Vulcan Crucible Steel Co., Div. of H. K. Porter Co., Inc. Chart showing more than 300 varieties of tool steel offered by 12 producers. (20)

Tool Steel. Joseph T. Ryerson & Son, Inc., 4 pp, illus. Discusses wear resistance, cost savings, color identification, machinability, forging, annealing, hardening and tempering of Ry-Alloy, an oil hardening tool steel supplied in rounds, squares and flats for applications such as arbors, clutch dogs, thrust washers and trimming dies. (22)

Spring Steels. Sandvik Steel, Inc., 6 pp, illus. Lists applications, finishes, sizes and chemical compositions of a line of spring steels. Briefly describes how spring steels are made. (23)

Zinc Coated Steel. Sharon Steel Corp., 12 pp, illus. Discusses welding, soldering, cold forming, cleaning and storage of Galvanite zinc coated steel. Shows applications and gives dimensional data. (24)

Stainless Strip. Superior Steel Corp., 32 pp, illus. Technical information on 20 types of stainless strip steel. (25)

Hard Precision Steel Rods. Thomson Industries, Inc., 5 pp, illus. Explains advantages of "60 Case" hardened and ground material (AISI 1060) for shafting, rolls and guide rods. (26)

Constructional Steel. United States Steel Corp., 4 pp. Lists available forms, sizes, chemical composition and mechanical properties of T1, a low carbon, quenched and tempered alloy steel. (27)

Stainless Steel Tubing. Wallingford Steel Co., 8 pp, illus. Describes stainless, carbon and alloy steel tubing for ornamental, mechanical, pressure and aircraft use. (30)

Stainless Steel Sheet. Washington Steel Corp., 12 pp, illus. Care and use of type 430 MicroRold stainless steel sheet. Physical properties, fabrication and uses. (31)

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DATA
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Irons and Steels

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Gray Irons

Class[a] ➡	20	25	30
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.26	0.26	0.26
Thermal Conductivity (212 F), Btu/hr/sq ft/°F/ft	24–34	24–34	24–34
Coef of Ther Exp (32–212 F), per °F	6×10^{-6}	6×10^{-6}	6×10^{-6}
Magnetic Properties	Magnetic	Magnetic	Magnetic
Electrical Resistivity (68 F), microhm-cm	Varies from 50 to 200 depending on composition		
MECHANICAL PROPERTIES[b]			
Modulus of Elasticity in Tension, psi[c]	13, 12, 9 x 10^6	14, 13, 11.5 x 10^6	16, 15, 13.5 x 10^6
Tensile Strength (as cast), 1000 psi	24–29, 20–24, 15–19	27–33, 25–30, 20–24	35–40, 30–34, 20–24
Transverse Strength (as cast), 1000 lb[d]	1, 2, 5.2	1.25, 2.1, 5.5	1.4, 2.2, 7.3
Deflection (as cast), in.[d]	0.14, 0.25, 0.25	0.17, 0.27. 0.30	0.16, 0.28, 0.31
Modulus of Rupture (as cast), 1000 psi	50, 53, 40	57, 56, 42	63, 58, 56
Hardness (Brinell, as cast)[e]	200, 180, 170	205, 190, 175	210, 200, 180
Fatigue Strength (endurance limit, as cast), 1000 psi[f]	—, 10, —	—, 12.5, —	—, 14.5, —
Compressive Strength (as cast), 1000 psi[g]	100, 95, 90	—, 100, —	—, 115, —
Shear Strength (as cast), 1000 psi	—, 32, —	—, 37, —	—, 44, —
FABRICATING PROPERTIES	Gray cast iron, having a ferrite matrix in which graphite flakes are dispersed, has a machinability rating of 110. When a cast iron microstructure shows alloy segregation, free carbides, steadite and free pearlite, machinability is reduced and may be as low as 40. Some castings show several structures due to cooling rate and section size		
JOINING	Can be joined by gas welding; shielded metal-arc welding using special electrodes; carbon arc welding. Preheating necessary. Can be brazed with nonferrous filler metal		
CORROSION RESISTANCE	More resistant to some types of corrosion than carbon and low alloy steels, possibly because of graphite; cast iron soil pipe usually lasts longer than steel pipe, for example. Gray irons are resistant to strong sulfuric acid, cold concentrated phosphoric and nitric acids; attacked by dilute sulfuric, phosphoric and nitric acids. Resistant to many alkalis including sodium hydroxide, soda ash and ammonia		
USES	Machine bases, grates, housings, ornamental castings, sanitary wear, piston rings, pipe and fittings	Similar to class 20 where higher strength is required	Light brake drums, clutch plates, cylinder blocks, liners, impellers, pipe and fittings, grate bars, machine parts

[a]Specified min tensile strength, 1000 psi, ASTM A 48-48.
[b]Three values are given for light, medium and heavy sections, respectively.
[c]At ¼ transverse load.
[d]Bar diameters 0.875, 1.2 and 2.0 in., respectively. Distance between supports 12, 18 and 24 in., respectively.
[e]Considerably wider range obtainable by heat treatment.
[f]About 40% of tensile strength appears to be safe level for endurance limit.
[g]In general, compressive strength is three to five times tensile strength.

Gray Irons—concluded

Class[a] ➡	35	40	50	60
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.26	0.26	0.26	0.26
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	24–34	24–34	24–34	24–34
Coef of Ther Exp (32–212 F), per °F	6 x 10^6	6 x 10^6	6 x 10^6	6 x 10^6
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic
Elec Res (68 F), microhm-cm	Varies from 50 to 200 depending on composition			
MECHANICAL PROPERTIES[b]				
Mod of Elast in Tension[c], psi	17, 16, 14.5 x 10^6	18, 17, 15.5 x 10^6	19, 19, 18 x 10^6	20, 19.5, 19 x 10^6
Ten Str (as cast), 1000 psi	38–42, 35–40, 25–33	50, 40–48, 33–45	60, 50–57, 52	70, 60–66, 50–75
Transverse Str (as cast), 1000 lb[d]	1.5, 2.6, 8	1.75, 2.9, 10	2, 3.3, 10.7	2.5, 3.7, 15
Deflection (as cast), in.[d]	0.17, 0.28 –	0.16, 0.28, 0.30	0.18, 0.28, 0.30	0.13, 0.34, 0.40
Mod of Rupture (as cast), 1000 psi	70, 69, 63	80, 78, 76	91, 88, 82	114, 98, 115
Hardness (Brinell, as cast)[e]	220, 210, 190	230, 220, 210	260, 240, 230	300, 290, 275
Fatigue Str (end. limit, as cast), 1000 psi[f]	–, 17.5, –	–, 21, –	–, 25, –	–, –, –
Compr Str (as cast), 1000 psi[g]	150, 125, –	–, 143, –	–, 150, –	–, 170, –
Shear Str (as cast), 1000 psi	–, 43, –	–. 57, –	–, –, –	–, –, –
FABRICATING PROPERTIES	Gray cast iron, having a ferrite matrix in which graphite flakes are dispersed, has a machinability rating of 110. When a cast iron microstructure shows alloy segregation, free carbides, steatite and free pearlite, machinability is reduced and may be as low as 40. Some castings show several structures due to cooling rate and section size			
JOINING	Can be joined by gas welding, shielded metal-arc welding using special electrodes, carbon arc welding. Preheating necessary. Can be brazed with nonferrous filler metal			
CORROSION RESISTANCE	More resistant to some types of corrosion than carbon and low alloy steels, possibly because of graphite; cast iron soil pipe usually lasts longer than steel pipe, for example. Gray irons are resistant to strong sulfuric acid, cold concentrated phosphoric and nitric acids; and attacked by dilute sulfuric, phosphoric and nitric acids. Resistant to many alkalis including sodium hydroxide, soda ash and ammonia			
USES	Clutch plates, crankcases, light brake-drums, liners, sleeves, cylinder blocks, impellers, machine components	Gears, camshafts, heads, liners, valves, pumps, tube supports, dies, wheels	Gears, valves, heads, blocks, steam pressure castings, dies, compressors, pumps, rams	Special brake drums, pressure castings, crusher frames, hot forming dies, heavy duty gears, hydraulic cylinders

[a]Specified min tensile strength, 1000 psi, ASTM A 48-48.
[b]Three values are given for light, medium and heavy sections, respectively.
[c]At ¼ transverse load.
[d]Bar diameters 0.875, 1.2 and 2.0 in., respectively. Distance between supports, 12, 18 and 24 in., respectively.
[e]Considerably wider range obtainable by heat treatment.
[f]About 40% of tensile strength appears to be safe level for endurance limit.
[g]In general, compressive strength is three to five times tensile strength.

Nodular or Ductile Irons

Type ➡	80-60-3	60-45-10	100-75-04[a]
COMPOSITION, %	T.C. 3.3–3.8, Si 2.0–3.0, Mn 0.2–0.5, P 0.06–0.08, Ni 0–1.0, Mg 0.02–0.07	T.C. 3.4–4.0, Si 2.0–2.75, Mn 0.2–0.6, P 0.06–0.08, Ni 0–1.0, Mg 0.02–0.07	T.C. 3.4–3.8, Si 2.0–2.75, Mn 0.3–0.6, P 008 max, Ni 0–2.5, Mo.0-1.0,Mg0.02-0.07
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.257	0.257	0.257
Melting Temp Range, F	2050–2150	2050–2150	2050–2150
Thermal Conductivity (212 F), Btu/hr/sq ft/°F/ft	18	20	—
Coef of Ther Exp (70–400 F), per °F	6.6 x 10^{-6}	6.6 x 10^{-6}	6.6 x 10^{-6}
Electrical Resistivity (75 F), microhm-cm	68[b]	66[b]	—
MECHANICAL PROPERTIES			
Modulus of Elasticity in Tension, psi	22–25 x 10^6	22–25 x 10^6	22–25 x 10^6
Tensile Strength, 1000 psi	90–110	60–80	100–120
Yield Strength, 1000 psi	60–75	45–60	75–90
Elongation (in 2 in.), %	3–10	10–25	6–10
Hardness (Brinell)	200–270	140–190	200–240
Impact Strength (Charpy), ft-lb			
Unnotched	15–65	60–115	35–50
Notched	2–5	10–15	—
Fatigue Strength	Endurance ratio follows pattern of other ferrous materials. For soft ferritic materials, notched endurance ratio runs from 50-55%; with stronger irons, the ratio drops to 30-40% or lower		
Compressive Strength	Ratio of compressive strength to tensile strength is about 2 to 1		
Creep Strength (0.0001%/hr), psi			
800 F	19,000	14,000	—
1000 F	1750	4000	—
1200 F	480	550	—
1400 F	—	—	—
THERMAL TREATMENT			
Ferritic Structure (ferritizing anneal)	Heat in 1600–1650 F range, cool to 1300 F, hold 1-3 hr, furnace cool to 1100 F, air cool		
Pearlitic-Ferritic Structures	Heat to 1600–1650 F, cool rapidly, reheat at 1100–1300 F		
Pearlitic Structures	Normalize by air cooling from 1600–1650 F		
Tempered Structures	Quench from 1400–1650 F depending on composition, temper at 800–1300 F		
FABRICATING PROPERTIES			
Machinability	Depends on structure but has excellent machinability in both as-cast and annealed conditions		
Weldability	Can be welded by most fusion welding processes. For maximum ductility, welding should be done on fully annealed material. Composition affects weld quality. A 60 Ni-40% Fe filler wire is best for metal arc welding. Can be brazed with the lower melting BAg filler metals		
CORROSION RESISTANCE	Approx same corrosion resistance as gray irons of similar composition		
USES	Anvils for forging hammers; impellers, levers, cams, crankshafts, dies, jet engine burner support rings	Valve and pump bodies, pipe fittings, clamps, gear housings, tractor and farm machine parts	Track shoes, brake drums, gears, camshafts, pistons

[a]Obtained by heat treatment involving normalizing or quenching and tempering.
[b]Iron containing 1% silicon.

Nodular or Ductile Irons—concluded

Type →	120-90-02[a]	Heat Resistant	Austenitic
COMPOSITION, %	T.C. 3.4–3.8, Si 2.0–2.75, Mn 0.3–0.6, P 0.08 max, Ni 0–2.5, Mo 0–1.0, Mg 0.02–0.07	T.C. 2.8–3.8, Si 2.5–6.0, Mn 0.2–0.6, P 0.08 max, Ni 0–1.5, Mg 0.02–0.07	T.C. 3.0, Si 2.0–3.2, Mn 0.8–1.5, P 0.02 max, Ni 18–22, Cr 0–2.5
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.257	0.25	0.268
Melting Temp Range, F	2050–2150	2050–2150	2250
Thermal Conductivity (212 F), Btu/hr/sq ft/°F/ft	—	—	—
Coef of Ther Exp (70–400 F), per °F	6.6×10^{-6}	—	10.4×10^{-6}
Elec Res (75 F), microhm-cm	—	—	102
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	$22–25 \times 10^6$	$22–25 \times 10^6$	18.5×10^6
Tensile Strength, 1000 psi	120–150	60–100	58–68
Yield Strength, 1000 psi	90–125	45–75	32–38
Elongation (in 2 in.), %	2–7	0–20	7–40[b]
Hardness (Brinell)	240–325	140–300	140–200
Impact Strength (Charpy), ft-lb			
Unnotched	25–40	5–115	—
Notched	—	—	10–28[c]
Fatigue Strength	Endurance ratio follows pattern set with other ferrous materials. For soft ferritic materials, notched endurance ratio is 50–55%; with the stronger irons, ratio drops to 30–40% or lower		
Compressive Strength	Ratio of compressive strength to tensile strength is about 2 to 1		
Creep Strength (0.0001%/hr), psi			
800 F	—	—	18,500
1000 F	—	—	13,000
1200 F	—	—	5,700
1400 F	—	—	2,000
THERMAL TREATMENT			
Ferritic Structure (ferritizing anneal)	Heat in 1600–1650 F range, cool to 1300 F, hold 1–3 hr, furnace cool to 1100 F, air cool		—
Pearlitic-Ferritic Structures	Heat to 1600–1650 F, cool rapidly, reheat at 1100–1300 F		—
Pearlitic Structures	Normalize by air cooling from 1600–1650 F		—
Tempered Structures	Quench from 1400–1650 F depending on composition, temper at 800–1300 F		—
FABRICATING PROPERTIES			
Machinability	Depends on structure but is excellent in both as-cast and annealed conditions		
Weldability	Can be welded by most fusion welding processes. For maximum ductility, welding should be done on fully annealed material. Composition affects weld quality. A 60 Ni-40% Fe filler wire is best for metal arc welding. Can be brazed with the lower melting BAg filler metals		
CORROSION RESISTANCE	Approx same corrosion resistance as gray irons of similar composition		
USES	Machine guides, pinions, gears, cams, dies, track rollers	Grate boxes, sinter pots, lead pots, glass molds, furnace doors	Impellers, grids, paper mill machine parts, pumps, valves

[a]Obtained by heat treatment involving normalizing or quenching and tempering.
[b]25–40% with 10% chromium.
[c]V-notched.

Malleable Irons

Type and Grade →	Standard		Pearlitic
	32510	35018	
COMPOSITION, %	C 2.3–2.7, Si 1.5–0.8, Mn 0.55 max, P 0.18 max, S 0.20 max	C 2.0–2.45, Si 1.4–0.85, Mn 0.55 max, P 0.18 max, S 0.20 max	Same as standard grades except that manganese can be higher
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.259–0.263	0.259–0.263	0.259–0.263
Thermal Conductivity, Btu/hr/sq ft/°F/ft			
80 F	29.5	29.5	[a]
700 F	23.0	23.0	[a]
Coef of Ther Exp (68–750), per °F	6.6×10^{-6}	6.6×10^{-6}	[a]
Specific Heat (70–750), Btu/lb/°F	0.133	0.133	—
Electrical Resistivity (68 F), microhm-cm	32.0	32.0	38.19–41.17
Shrinkage Allowance (contraction minus expansion during anneal), in.	11/64–1/32	11/64–1/32	11/64–1/32
Magnetic Properties	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	25×10^6	25×10^6	28×10^6
Tensile Strength, 1000 psi	50–52	53–60	60–90
Yield Strength, 1000 psi	32–35	35–40	40–70
Elongation (in 2 in.), %	10–18	18–25	12–3
Reduction of Area, %	18–23	18–23	—
Hardness (Brinell)	110–145	110–145	160–285
Impact Strength[c] (Charpy), ft-lb	16.5	16.5	12
Fatigue Strength			
Endurance Limit, 1000 psi	25	31	30–32
Endurance Ratio	0.50	0.50	—
Mod of Elast in Compression, psi	25×10^5	25×10^5	—
Compressive Yield Strength, 1000 psi			
1% Permanent Set	28	28	43
At Failure	90+	90+	—
Ultimate Shear Strength, 1000 psi	45–48	48–54	—
Yield Strength in Shear, 1000 psi	29–32	32–36	—
Mod of Rupture in Torsion, psi	58,000	58,000	—
Poisson's Ratio	0.17	0 17	—
Allowable Working Stress (775 F), psi	5600	5600	—
THERMAL TREATMENT			
Hardening Temp, F	1500[b]	1500[b]	1500
Tempering Temp, F	—	—	About 600
FABRICATING PROPERTIES			
Casting Temperature Range, F	2600–2800	2600–2850	2600–2850
Machinability Index (AISI B1112 steel = 100)	120	120	80–90
Weldability	Not fusion welded. Can be soldered and brazed		
CORROSION RESISTANCE	Resistant to atmospheric corrosion in rural, industrial and marine atmospheres; fresh and salt waters		
USES	Gear cases, brake supports, journal boxes, pipe fittings, pole line hardware, ordnance parts, marine deck fittings, anchors, parts for domestic appliances and business machines		Rocker arms, camshafts, gears, sprockets, tractor parts, agricultural machinery parts

[a] Estimated to be somewhat higher than for standard grades.
[b] Must be first heated to 1700 F to dissolve graphitic carbon.
[c] V-notch 0.079 in. deep, 0.394-in. sq bar.

Ingot and Wrought Irons

Type ➡	Ingot Iron	Wrought Iron	
COMPOSITION, %	C<0.02, Mn<0.02, Si trace, P 0.005, S 0.02	C 0.02, Mn 0.03, Si 0.15, P 0.12, S 0.02, Slag 3.0	
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.28	0.25	
Melting Point, F	2794	2750	
Thermal Conductivity (212 F), Btu/hr/sq ft/°F/ft	38	36	
Coef of Ther Exp (68–212 F), per °F	6.8×10^{-6}	6.7×10^{-6}	
Specific Heat, Btu/lb/°F	0.11	0.11	
Electrical Resistivity (68 F), microhm-cm	9.7	—	
Magnetic Properties	Magnetic	Magnetic	
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	29.8×10^6	29×10^6	
		Longitudinal[a]	Transverse[a]
Tensile Strength, 1000 psi			
Annealed	42	—	—
Hot Rolled	44	47	34
Cold Drawn	73	—	—
Yield Point, 1000 psi			
Annealed	19	—	—
Hot Rolled	23	24	23
Cold Drawn	69	—	—
Elongation (in 2 in.), %			
Annealed	48	—	—
Hot Rolled	47	35	7
Cold Drawn	12	—	—
Reduction of Area, %			
Annealed	76	—	—
Hot Rolled	75	48	12
Cold Drawn	63	—	—
Hardness (Brinell)			
Annealed	69	—	—
Hot Rolled	83	105	105
Cold Drawn	142	—	—
Impact Strength (Charpy), ft-lb			
Annealed	19	—	—
Hot Rolled	—	29	11
Cold Drawn	—	—	—
Fatigue Strength (endurance limit), 1000 psi			
Annealed	26	—	—
Hot Rolled	28	23	19
Cold Drawn	33	—	—
FABRICATING PROPERTIES			
Annealing Temperature, F	1700–1800	1300–1400	
Forging Temperature Range, F	—	2100–2200	
Bending Temperature Range, F	—	1300–1400	
Machinability Index (AISI B1112 Steel = 100)	50	50	
Weldability	Readily joined by resistance, arc and gas methods		
CORROSION RESISTANCE	Like other ferrous metals with the exception of the stainless steels, these materials generally require protection for extended service under corrosive conditions. In spite of its purity, ingot iron has corrosion rates much the same as those of plain carbon steel. Under atmospheric conditions, wrought iron appears to be somewhat superior to carbon steel. In fresh water the two materials have similar characteristics; there is some dispute for salt water service		
AVAILABLE FORMS	Sheet and strip, wire, rail sections	Tubular products, plate, sheet, bars, structural shapes, wire, chain	
USES	Deep drawn parts, enameling stock, third rails, wire for electrical apparatus	Oil-well casing, heat exchangers, piping for fresh and salt water, tanks, bolts and nuts, roofing, chemical processing equipment, chains	

[a]As rolled.

Low Carbon Steels

AISI Type →	C1010	C1015	C1018	C1020	C1025
COMPOSITION, %	C 0.08–0.13, Mn 0.30–0.50, P 0.040 max, S 0.050 max	C 0.13–0.18, Mn 0.30–0.60, P 0.040 max, S 0.050 max	C 0.15–0.20, Mn 0.60–0.90, P 0.040 max, S 0.050 max	C 0.18–0.23, Mn 0.30–0.60, P 0.040 max, S 0.050 max	C 0.22–0.28, Mn 0.30–0.60, P 0.040 max, S 0.050 max
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.283	0.283	0.283	0.283	0.283
Melting Temp Range, F	2750–2775	2750–2775	2750–2775	2750–2775	2750–2775
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.4×10^{-6}	8.4×10^{-6}	8.4×10^{-6}	8.4×10^{-6}	8.4×10^{-6}
Spec Ht, Btu/lb/°F	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11
Elec Res (68 F), microhm-cm	14.3	14.3	14.3	14.3	14.3
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$
Ten Str, 1000 psi					
Hot Rolled	51	61	69	65	70
Cold Worked	56	74	82	78	80
Yld Str, 1000 psi					
Hot Rolled	29	46	48	43	45
Cold Worked	33	62	70	66	69
Elong (in 2 in.), %					
Hot Rolled	38	39	38	36	31
Cold Worked	35	24	20	20	18
Red. of Area, %					
Hot Rolled	70	61	62	59	58
Cold Worked	65	57	57	55	48
Hardness (Brinell)					
Hot Rolled	101	126	143	143	143
Cold Worked	113	143	163	156	162
Impact Str	Markedly dependent on section size and processing details, such as deoxidation practice, rolling practice, etc. Impact strength is affected a great deal more than other mechanical properties by these variables				
Fatigue Str	Dependent on thermal and mechanical history, though not to the extent that impact strengths are. Conservative estimate of fatigue strength is 40–50% of tensile strength				
THERMAL TREATMENT					
Annealing Temp, F	1650–1750	1650–1750	1650–1750	1650–1750	1600–1700
Hardening Temp, F	1650–1700[a]	1650–1700[a]	1650–1700[a]	1600–1675[b]	1600–1675[b]
Tempering Temp, F	300–1350	300–1350	300–1350	300–1350	300–1350
FABRICATING PROPERTIES					
Machinability Index[c]					
Hot Rolled	40	50	52	50	52
Cold Worked	45	58	65	60	65
Weldability	Easily welded by all commercial welding procedures, including gas, arc, bronze, thermit, oxyacetylene and submerged-melt processes. Resulting welds are of extremely high quality				
CORROSION RESISTANCE	Rusted by oxygen and water at room temperature, rate of attack increasing sharply as pH goes above 4 and decreasing below a pH of 8. Dilute salt solutions increase corrosion rate. Attacked by acids, in general, but satisfactorily resistant to alkalis at normal temperatures. Corrosion rate in ordinary rusting not appreciably affected by carbon or alloy content or by cold working				
AVAILABLE FORMS	Can be obtained in all mill forms. "Structural mild steel," in which the common shapes are supplied unless otherwise specified, falls somewhere in these ranges of composition				
USES	Can be carburized to give a hard surface on a part which retains its tough inner core. Machine applications apart from structural shapes include automobile spiders, gears, clutch disks, bolts, bearing races, camshafts, crankshafts, piston pins, cams, pneumatic tool cylinders, gun blocks, bushings, stud and collar bolts, shifter shoes, draw bars, pivot pins, cap screws, precision shafting, scythe blade heels, flanges, shackles, tie rods, drag links, steering gear connecting rods, thrust washers, wrenches				

[a]Quench in water, brine or caustic frequently used.
[b]Soluble oil solution used for hardening bolts; mineral oil used when quenching for machinability.
[c]Based on AISI B1112 steel = 100.

Medium Carbon Steels

AISI Type →	C1030	C1035	C1040	C1045
COMPOSITION, %	C 0.28–0.34, Mn 0.60–0.90, P 0.040 max, S 0.050 max	C 0.32–0.38, Mn 0.60–0.90, P 0.040 max, S 0.050 max	C 0.37–0.44, Mn 0.60–0.90, P 0.040 max, S 0.050 max	C 0.43–0.50, Mn 0.60–0.90, P 0.040 max, S 0.050 max
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.283	0.283	0.283	0.283
Melting Temp Range, F	2700–2750	2700–2750	2700–2750	2700–2750
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.3×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.3×10^{-6}
Specific Heat, Btu/lb °F	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11
Elec Res (68 F), microhm-cm	19	19	19	19
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$
Ten Str, 1000 psi				
Hot Rolled	80	85	91	98
Cold Worked	85	92	100	103
Hard. & Temp	98[a]	103[b]	113[b]	120[c]
Yld Str, 1000 psi				
Hot Rolled	50	54	58	59
Cold Worked	72	79	88	90
Hard. & Temp	70[a]	72[a]	86[b]	90[b]
Elong (in 2 in.), %				
Hot Rolled	30	30	27	24
Cold Worked	26	25	17	14
Hard. & Temp	27[a]	23[b]	23[b]	18[b]
Red. of Area, %				
Hot Rolled	56	53	50	45
Cold Worked	51	50	42	40
Hard. & Temp	64[a]	59[b]	62[b]	52[c]
Hardness (Brinell)				
Hot Rolled	163	183	201	212
Cold Worked	179	201	207	217
Hard. & Temp	212[a]	230[b]	235[b]	277[c]
Impact Str	Markedly dependent on section size and processing details such as deoxidation practice, rolling practice, etc.—more so than other mechanical properties			
Fatigue Str	Dependent on thermal and mechanical history, though not to the extent that impact strengths are. A conservative estimate of fatigue strength is 40–50% of tensile strength			
THERMAL TREATMENT				
Annealing Temp, F	1550–1700	1500–1650	1450–1600	1450–1600
Hardening Temp, F[d]	1575–1650	1525–1600	1500–1575	1475–1550
Tempering Temp, F	300–1350	300–1350	300–1350	300–1350
FABRICATING PROPERTIES				
Machinability Index (AISI B1112 steel=100)				
Cold Worked	67	67	65	60
Hard. & Temp	55	55	55	50
Weldability	Easily welded by all commercial procedures including gas, arc bronze, thermit, oxyacetylene and submerged-melt. Preheat and postheat treatments frequently necessary			
CORROSION RESISTANCE	Rusted by oxygen and water at room temperature, rate of attack increasing sharply as the pH goes above 4 and decreasing below a pH of 8. Dilute salt solutions increase corrosion rate. Attacked by acids, in general, but are satisfactorily resistant to alkalis at normal temperatures. Corrosion rate in ordinary rusting not appreciably affected by carbon or alloy content or by cold working			
AVAILABLE FORMS	Can be furnished in all standard mill forms			
USES	Shafts brake shoe parts, gears, tie rods, brake and clutch pedals, truck rim side rings, sucker rods, connecting rods, shifter levers, pitman arms, flywheel rings, I-beam axles, crankshafts, camshafts, wheel hubs, pins, tools, plowshares, sway bars, mine bits, lock washers, bumper bars, springs, road scraper blades, scarifier teeth, grinding balls			

[a] 1-in. round water quenched 1575 F, drawn at 1000 F. [b] 1-in. round water quenched 1525 F, drawn at 1000 F.
[c] 1-in. round water quenched 1550 F, drawn at 1000 F. [d] Quenched in oil, water, or brine or caustic solutions.

High Carbon Steels

AISI Type →	C1055	C1060	C1070	C1080	C1095
COMPOSITION, %	C 0.50–0.60, Mn 0.60–0.90, P 0.040 max, S 0.050 max	C 0.55–0.65, Mn 0.60–0.90, P 0.040 max, S 0.050 max	C 0.65–0.75, Mn 0.60–0.90, P 0.040 max, S 0.050 max	C 0.75–0.88, Mn 0.60–0.90, P 0.040 max, S 0.050 max	C 0.90–1.05, Mn 0.30–0.50, P 0.040 max, S 0.050 max
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.283	0.283	0.283	0.283	0.283
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.1×10^{-6}	8.1×10^{-6}	8.1×10^{-6}	8.1×10^{-6}	8.1×10^{-6}
Spec Ht, Btu/lb/°F	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11
Elec Res (68 F), microhm-cm	18	18	18	18	18
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$
Ten Str, 1000 psi					
Annealed (1450 F)	97	105	112	119	100
Hot Rolled	109	116	128	141	142
Hard. & Temp	150[a]	160[a]	174[b]	189[b]	180[c]
Yld Str, 1000 psi					
Annealed	52	54	60	66	53
Hot Rolled	65	70	77	84	84
Hard. & Temp	105	112	127	142	118
Elong (in 2 in.), %					
Annealed	24	20	17	15	21
Hot Rolled	19	17	15	12	9
Hard. & Temp	14	12	13	14	11
Red. of Area, %					
Annealed	47	44	34	22	42
Hot Rolled	38	36	27	17	18
Hard. & Temp	45	40	37	34	30
Hardness (Brinell)					
Annealed	185	192	207	223	197
Hot Rolled	235	241	267	293	293
Hard. & Temp	307	321	354	388	375
Impact Str (Izod), ft-lb					
Annealed	22	15	11	6	5
Hot Rolled	18	13	9	5	3
Hard. & Temp	22	15	13	10	5
THERMAL TREATMENT					
Normalizing Temp, F	1525–1650	1525–1650	1525–1650	1525–1650	1525–1650
Annealing Temp, F	1500–1575	1500–1575	1500–1575	1500–1575	1500–1575
Hardening Temp, F	1450–1550	1450–1550	1450–1525	1450–1500	1430–1500
Tempering Temp, F	400–1300	400–1300	400–1300	400–1300	400–1300
FABRICATING PROPERTIES					
Hot Working Temp Range, F	1550–1650	1550–1650	1550–1650	1550–1650	1550–1650
Machinability Index (annealed)[d]	55	53	45	44	43
Weldability	High carbon content introduces difficulties in welding. Can be welded satisfactorily by thermit process. Welding by gas and arc methods is difficult, and resulting welds are only moderately satisfactory				
CORROSION RESISTANCE	Rust when brought into contact with moisture and air at room temperature; rates not appreciably affected by carbon content. If salts are present, corrosion rate is increased. Attacked readily by acids, but resistant to alkalis at ordinary temperatures				
AVAILABLE FORMS	Furnished in the form of cold rolled strip, hot rolled strip, flat bars and forgings				
USES	Heavy machine parts, such as shafts, braces and control rods; hand tools, including open-end and Stillson wrenches, hammers, pliers, screwdrivers, hatchets and axes; agricultural machinery parts, such as plowshares, mold boards, disks for harrows, and mower knives, and flat and helical springs				

[a] 1-in. round, normalized 1650 F, reheated to 1550 F, oil quenched, tempered 700 F.
[b] 1-in. round, normalized 1650 F, reheated to 1525 F, oil quenched, tempered 700 F.
[c] 1-in. round, normalized 1650 F, reheated to 1475 F, oil quenched, tempered 700 F.
[d] Based on AISI B1112 steel = 100.

Free-Cutting Steels

AISI Type[a] →	B1111, C1211	B1112, C1212	B1113, C1213
COMPOSITION, %	C 0.13 max, Mn 0.60–0.90, P 0.07–0.12, S 0.08–0.15	C 0.13 max, Mn 0.70–1.00, P 0.07–0.12, S 0.16–0.23	C 0.13 max, Mn 0.70–1.00, P 0.07–0.12, S 0.24–0.33
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.283	0.283	0.283
Thermal Conductivity (212 F), Btu/hr/sq ft/°F/ft	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.4×10^{-6}	8.4×10^{-6}	8.4×10^{-6}
Specific Heat, Btu/lb/°F	0.10–0.11	0.10–0.11	0.10–0.11
Electrical Resistivity (68 F), microhm-cm	14.3	14.3	14.3
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	29×10^6	29×10^6	29×10^6
Tensile Strength, 1000 psi[c]			
9/16 In. Dia	85–110	85–110	85–110
1-In. Dia	80–105	80–105	80–105
2-In. Dia	70–90	70–90	70–90
Yield Strength, 1000 psi[c]			
9/16-In. Dia	75–100	75–100	75–100
1-In. Dia	70–90	70–90	70–90
2-In. Dia	60–85	60–85	60–85
Elongation (in 2 in.), %[c]			
9/16-In. Dia	10–20	10–20	10–20
1-In. Dia	12–22	12–22	12–22
2-In. Dia	10–20	10–20	10–20
Reduction of Area, %[c]			
9/16-In. Dia	30–50	30–50	30–50
1-In. Dia	35–55	35–55	35–55
2-In. Dia	30–50	30–50	30–50
Hardness (*Brinell*)[c]			
9/16-In. Dia	B90–102[b]	B90–102[b]	B90–102[b]
1-In. Dia	163–229	163–229	163–229
2-In. Dia	149–202	149–202	149–202
Impact Strength	Relatively low impact strength at low temperatures; should not be used for shock loading applications at subzero temperatures		
Fatigue Strength	Notch sensitive; as cold drawn. Polished fatigue specimens will show expected values but poor finishing or processing of parts may cause low and erratic results for finished parts under dynamic or alternating stresses of relatively low intensity		
THERMAL TREATMENT			
Case Hardening	Case hardened for high surface hardness and good wear resistance where core properties not important. Case hardness Rockwell C60–65		
Case Hardening Temp, F[d]	1450–1700	1450–1700	1450–1700
Tempering Temp, F	300	300	300
FABRICATING PROPERTIES			
Workability	Not recommended for operations involving cold metal movement, such as crimping, forming or bending		
Machinability Index[e]	90	100	125
Machining Speed (avg), sfm	153	170	213
AVAILABLE FORMS	Cold drawn shapes		
USES	Studs, nuts, fasteners, sleeves, collars, spacers, dowels, rods, handles, levers		

[a] B1111, B1112, B1113 are Bessemer Steels. C1211, C1212, C1213 are basic open hearth steels.
[b] Rockwell hardness.
[c] Cold drawn.
[d] Quench in water or oil.
[e] Based on B1112 = 100.

Manganese Steels

AISI Type →	1320	1321	1330	1335	1340
COMPOSITION, %	C 0.18–0.23, Mn 1.60–1.90, Si 0.20–0.35, P 0.040 max, S 0.040 max	C 0.17–0.22, Mn 1.80–2.10, Si 0.20–0.35, P 0.050 max, S 0.050 max	C 0.28–0.33, Mn 1.60–1.90, Si 0.20–0.35, P 0.040 max, S 0.040 max	C 0.33–0.38, Mn 1.60–1.90, Si 0.20–0.35, P 0.040 max, S 0.040 max	C 0.38–0.43, Mn 1.60–1.90, Si 0.20–0.35, P 0.040 max, S 0.040 max
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.283	0.283	0.283	0.283	0.283
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27	27
Coef of Ther Exp (68–1200 F), per °F	7.9×10^{-6}	7.9×10^{-6}	7.9×10^{-6}	7.9×10^{-6}	7.9×10^{-6}
Spec Ht, Btu/lb/°F	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11
Elec Res (68 F), microhm-cm	17	17	17	17	17
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES[a]					
Mod of Elast in Tension, psi	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$
Ten Str, 1000 psi					
Annealed	84	90	97	104	110
Cold Drawn	102	107	113	119	—
Hard. & Temp	100[b]	—	122[c]	126[d]	137[d]
Yld Point, 1000 psi					
Annealed	72	80	83	90	94
Cold Drawn	80	87	93	100	—
Hard. & Temp	73.5	—	100	105	118
Elong (in 2 in.), %					
Annealed	24	22	21	19.5	18
Cold Drawn	20	18	15	14	—
Hard. & Temp	28	—	19	20.5	19
Red. of Area, %					
Annealed	60	58	57	55	54
Cold Drawn	57	55	50	47	—
Hard. & Temp	65	—	52	59	55
Hardness (Brinell)					
Annealed	179	187	197	212	223
Cold Drawn	207	212	235	248	—
Hard. & Temp	217	—	248	262	285
Impact Str (Izod), ft-lb					
Annealed	—	—	—	—	52
Cold Drawn	80	—	—	—	56
THERMAL TREATMENT					
Annealing Temp, F	1500–1600	1500–1600	1500–1600	1500–1600	1500–1600
Hardening Temp, F	1575–1625	1575–1625	1500–1575	1500–1550	1500–1550
FABRICATING PROPERTIES					
Machinability Index[e] (annealed or cold drawn)	65	63	62	62	59
Weldability	Manganese increases crack sensitivity of welded joints, particularly when this sensitivity is associated with higher carbon contents. Appropriate control of welding practice must accordingly be employed				
CORROSION RESISTANCE	Rust at rates similar to those of carbon steels when brought into contact with moisture and air. If salts are present, corrosion rates are increased. Attacked readily by acids, but resistant to alkalis at ordinary temperatures				
AVAILABLE FORMS	Billets, hot rolled bars, cold finished bars, forgings				
USES	Automotive, farm implement and miscellaneous industrial applications, including axles, drive shafts, propeller shafts, bolts, studs, gears and tie rods				

[a]Mechanical properties determined on 1-in. round bars.
[b]Pseudo-carburized at 1700 F for 8 hr, oil quenched, tempered at 300 F, reheated at 1475 F.
[c]Water quenched from 1525 F, tempered at 1000 F.
[d]Oil quenched from 1525 F, tempered at 1000 F.
[e]Based on AISI B1112 steel = 100.

Nickel Steels

AISI Type ➡	2317	2330	2335	2340	2345
COMPOSITION, %	C 0.15–0.20, Mn 0.40–0.60, Si 0.20–0.35, Ni 3.25–3.75	C 0.28–0.33, Mn 0.60–0.80, Si 0.20–0.35, Ni 3.25–3.75	C 0.33–0.38, Mn 0.60–0.80, Si 0.20–0.35, Ni 3.25–3.75	C 0.38–0.43, Mn 0.70–0.90, Si 0.20–0.35, Ni 3.25–3.75	C 0.43–0.48, Mn 0.70–0.90, Si 0.20–0.35, Ni 3.25–3.75
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.283	0.283	0.283	0.283	0.283
Melting Point, F	2620	2600	2590	2585	2575
Ther Cond (120 F), Btu/hr/sq ft/°F/ft	38.3	38.3	38.3	38.3	38.3
Coef of Ther Exp, per °F					
0 to 200 F	6.2 x 10^{-6}	6.2 x 10^{-6}	6.2 x 10^{-6}	6.2 x 10^{-6}	6.2 x 10^{-6}
0 to 1200 F	8.0 x 10^{-6}	8.0 x 10^{-6}	8.0 x 10^{-6}	8.0 x 10^{-6}	8.0 x 10^{-6}
Spec Ht (68–212 F), Btu/lb/°F	0.11–0.12	0.11–0.12	0.11–0.12	0.11–0.12	0.11–0.12
Elec Res (annealed), microhm-cm					
120 F	28.4	28.4	28.4	28.4	28.4
570 F	46.8	46.8	46.8	46.8	46.8
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES[a]					
Mod of Elast in Tension, psi	29–30 x 10^6	29–30 x 10^6	29–30 x 10^6	29–30 x 10^6	29–30 x 10^6
Ten Str, 1000 psi					
Hot Rolled	81	97	103	110	115
Annealed	77	90	95	100	104
Cold Drawn	95	110	—	—	—
Hard. & Temp (1000 F)[b]	107	125	137	137	140
Yld Str, 1000 psi					
Hot Rolled	55	67	72	76	80
Annealed	53	64	68	71	75
Cold Drawn	75	90	—	—	—
Hard. & Temp (1000 F)[b]	72	96	119	119	130
Elong (in 2 in.), %					
Hot Rolled	29	24	22	21	19
Annealed	31	27	25	23	22
Cold Drawn	25	17	—	—	—
Hard. & Temp (1000 F)[b]	27	22	21	21	20
Red. of Area, %					
Hot Rolled	62	51	47	44	40
Annealed	61	54	51	50	46
Cold Drawn	58	47	48	48	40
Hard. & Temp (1000 F)[b]	71	60	59	59	58
Hardness (Brinell)					
Hot Rolled	160	195	205	220	230
Annealed	152	180	190	200	210
Cold Drawn	197	235	235	235	255
Hard. & Temp (1000 F)[b]	222	270	302	302	302
Impact Str (Izod, hard. & temp at 1000 F)[b], ft-lb	84	55	52	49	40
THERMAL TREATMENT					
Annealing Temp, F	1550	1500	1475	1450	1450
Normalizing Temp, F	1550	1500	1475	1450	1450
Hardening Temp, F	1475	1450	1450	1425	1400
FABRICATING PROPERTIES					
Max Forging Temp, F	2300	2250	2225	2200	2175
Machinability Index[c]	55	50	45	45	40
Weldability	Good. Preheating desirable except AISI 2317				
CORROSION RESISTANCE	Better corrosion resistance than plain carbon steels				
AVAILABLE FORMS	Usually supplied as bar stock or forgings, but can be obtained in all steel mill forms				
USES	Carburized parts; gears, cams	Shafting, heavy forgings, gears, highly stressed bolts, axles, other highly stressed parts			

[a]For design purposes, fatigue strength is approximately 50% of tensile strength. Compressive yield strength is about equal to tensile yield strength. Shear strength is about 5 to 10% less than tensile strength.
[b]Properties after heat treatment are based on oil quench and 1-in. round bars.
[c]Based on AISI B1112 steel = 100.

continued

Nickel Steels—concluded

AISI Type →	2512	2515	2517
COMPOSITION, %	C 0.09-0.14, Mn 0.40-0.60, Si 0.20-0.35, Ni 4.75-5.25	C 0.12-0.17, Mn 0.40-0.60, Si 0.20-0.35, Ni 4.75-5.25	C 0.15-0.20, Mn 0.40-0.60, Si 0.20-0.35, Ni 4.75-5.25
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.283	0.283	0.283
Melting Point, F	2620	2615	2610
Thermal Conductivity (120 F), Btu/hr/sq ft/°F/ft	34.5-38.5	34.5-38.5	34.5-38.5
Coef of Ther Exp, per °F			
0 to 200 F	6.0×10^{-6}	6.0×10^{-6}	6.0×10^{-6}
0 to 1200 F	7.8×10^{-6}	7.8×10^{-6}	7.8×10^{-6}
Specific Heat (68-212 F), Btu/lb/°F	0.11-0.12	0.11-0.12	0.11-0.12
Elec Res (annealed, 120 F), microhm-cm	27-29	27-29	27-29
Magnetic Properties	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi[a]	$29-30 \times 10^6$	$29-30 \times 10^6$	$29-30 \times 10^6$
Tensile Strength, 1000 psi			
Hot Rolled	86	90	92
Annealed	77	80	82
Cold Drawn	—	103	—
Hard. & Temp (1000 F)[b]	105	113	120
Yield Strength, 1000 psi			
Hot Rolled	62	67	70
Annealed	61	63	65
Cold Drawn	—	75	—
Hard. & Temp (1000 F)[b]	85	94	100
Elongation (in 2 in.), %			
Hot Rolled	28	26	26
Annealed	30	25	29
Cold Drawn	—	24	—
Hard. & Temp (1000 F)	28	25	22
Reduction of Area, %			
Hot Rolled	70	67	65
Annealed	72	71	70
Cold Drawn	—	62	—
Hard. & Temp (1000 F)[b]	73	69	66
Hardness (Brinell)			
Hot Rolled	170	180	184
Annealed	157	160	162
Cold Drawn	—	207	—
Hard. & Temp (1000 F)[b]	217	233	244
Impact Str (Izod, hard. & temp at 1000 F[b]), ft-lb	95	85	80
THERMAL TREATMENT			
Annealing Temp, F	1525	1500	1500
Normalizing Temp, F	1525	1500	1500
Hardening Temp, F	1475	1475	1475
FABRICATING PROPERTIES			
Max Forging Temp, F	2300	2300	2300
Machinability Index[c]	—	40	—
Weldability	Good	Good	Good
CORROSION RESISTANCE	Better corrosion resistance than plain carbon steels		
AVAILABLE FORMS	Usually supplied as bars, tubing or forgings, but can be obtained in all steel mill forms		
USES	Heavy duty carburized parts such as aircraft gears and piston pins. Uncarburized, these steels are used for corrosion resistant equipment in paper and oil industries		

[a]For design purposes, fatigue strength is approximately 50% of tensile strength. Compressive yield strength is about equal to tensile yield strength. Shear strength is about 5 to 10% less than tensile strength.
[b]Properties after heat treatment are based on oil quench and 1-in. round bars.
[c]Based on AISI B1112 steel = 100.

Carbon-Molybdenum Steels

AISI Type →	4023	4032	4042	4053	4063
COMPOSITION, %	C 0.20–0.25, Mn 0.70–0.90, P 0.040 max, S 0.040 max, Si 0.20–0.35, Mo 0.20–0.30	C 0.30–0.35, Mn 0.70–0.90, P 0.040 max, S 0.040 max, Si 0.20–0.35, Mo 0.20–0.30	C 0.40–0.45, Mn 0.70–0.90, P 0.040 max, S 0.040 max, Si 0.20–0.35, Mo 0.20–0.30	C 0.50–0.56, Mn 0.75–1.00, P 0.040 max, S 0.040 max, Si 0.20–0.35, Mo 0.20–0.30	C 0.60–0.67, Mn 0.75–1.00, P 0.040 max, S 0.040 max, Si 0.20–0.35, Mo 0.20–0.30
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.283	0.283	0.283	0.283	0.283
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.3×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.3×10^{-6}
Spec Ht, Btu/lb/°F	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11
Elec Res (68 F), microhm-cm	19	19	19	19	19
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$
Ten Str, 1000 psi					
Annealed, Cold Drawn	88	92	96	102	109
Cold Drawn	90	104	117	127	137
Hard. & Temp	120[a], 108[b]	210[c], 140[d]	235[e], 158[f]	250[g], 165[h]	269[i], 173[j]
Yld Point, 1000 psi					
Annealed, Cold Drawn	76	79	82	88	94
Cold Drawn	75	89	101	108	115
Hard. & Temp	85[a], 64[b]	182[c], 128[d]	210[e], 140[f]	223[g], 150[h]	231[i], 150[j]
Elong (in 2 in.), %					
Annealed, Cold Drawn	22	20	19	18	16
Cold Drawn	21	17	16	14	13
Hard. & Temp	20[a], 21[b]	11[c], 18[d]	10[e], 15[f]	12[g], 16[h]	8[i], 13[j]
Red. of Area, %					
Annealed, Cold Drawn	57	54	53	51	48
Cold Drawn	55	51	49	45	40
Hard. & Temp	53[a], 54[b]	49[c], 63[d]	42[e], 60[f]	40[g], 56[h]	15[i], 40[j]
Hardness (Brinell)					
Annealed, Cold Drawn	179	192	202	212	223
Cold Drawn	183	217	241	262	277
Hard. & Temp	255[a], 229[b]	415[c], 302[d]	461[e], 302[f]	495[g], 352[h]	534[i], 380[j]
Fatigue Str, 1000 psi	Endurance limit is proportional to tensile strength in same ratio as in other low alloy steels. Below 400 Bhn, ratio is about 50%; at higher hardness it is about 45% of tensile strength				
THERMAL TREATMENT					
Annealing Temp. F	1650 [k]	1550–1600 [l]	1525–1575	1450–1550	1450–1550
Hardening Temp (oil quench), F			1500–1575	1475–1550	1475–1550
FABRICATING PROPERTIES					
Machinability Index (AISI B1112 = 100)	73	70	65	56	52
Weldability	Can be welded by procedures used for carbon steels. Molybdenum increases hardenability; preheating or postheating may be required				
CORROSION RESISTANCE	Similar to carbon steels				
USES	Automotive parts such as countershafts, transmission shafts, spline and differential gears	Automotive transmission gears and pinions, bolts	Leaf and coil springs, bolts, axles, steering arms and knuckles. Hand tools such as screw drivers	Leaf and coil springs. Hand tools such as chisels	

[a] 1-in. round pseudo-carburized 8 hrs at 1700 F, oil quenched, tempered 1 hr at 300 F.
[b] Same as [a] but reheated at 1475 F, oil quenched.
[c] Water quenched from 1525 F, tempered at 600 F.
[d] Water quenched from 1525 F, tempered at 1000 F.
[e] Oil quenched from 1500 F, tempered at 600 F.
[f] Oil quenched from 1500 F, tempered at 1000 F.
[g] Oil quenched from 1475 F, tempered at 600 F.
[h] Oil quenched from 1475 F, tempered at 1000 F.
[i] Oil quenched from 1450 F, tempered at 600 F.
[j] Oil quenched from 1450 F, tempered at 1000 F.
[k] Carburize 1650-1700 F; quench fine grained steels directly from carburizing temperature.
[l] Carburize 1650-1700 F; quench fine grained steels directly from carburizing temperature. Water quench from 1500-1550 F if not carburized.

Nickel-Chromium-Molybdenum Steels (4300)

AISI Type →	4317	4320	4337	4340
COMPOSITION, %	C 0.15–0.20, Mn 0.45–0.65, Ni 1.65–2.00, Cr 0.40–0.60, Mo 0.20–0.30	C 0.17–0.22, Mn 0.45–0.65, Ni 1.62–2.00, Cr 0.40–0.60, Mo 0.20–0.30	C 0.35–0.40, Mn 0.60–0.80, Ni 1.65–2.00, Cr 0.70–0.90, Mo 0.20–0.30	C 0.38–0.43, Mn 0.60–0.80, Ni 1.65–2.00 Cr 0.70–0.90, Mo 0.20–0.30
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.283	0.283	0.283	0.283
Melting Point, F	2750	2750	2740	2740
Ther Cond (120 F), Btu/hr/sq ft/°F/ft	21.7	21.7	21.7	21.7
Coef of Ther Exp, per °F				
0 to 200 F	6.3×10^{-6}	6.3×10^{-6}	6.3×10^{-6}	6.3×10^{-6}
0 to 1200 F	8.1×10^{-6}	8.1×10^{-6}	8.1×10^{-6}	8.1×10^{-6}
Spec Ht, Btu/lb/°F	0.107	0.107	0.107	0.107
Elec Res, microhm-cm				
120 F	30	30	30	30
570 F	48	48	48	48
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$
Ten Str, 1000 psi				
As Rolled	122	134	180	192
Annealed	95	98	115	119
Hard. & Temp[a]	160[b]	180[b]	140[c], 210[d]	150[c], 220[d]
Yld Str, 1000 psi				
As Rolled	99	102	141	147
Annealed	77	89	96	99
Hard. & Temp[a]	130[b]	154[b]	120[c], 190[d]	130[c], 200[d]
Elong (in 2 in.), %				
As Rolled	19	17	11	9
Annealed	25	23	19	17
Hard. & Temp[a]	17[b]	15[b]	21[c], 14[d]	19[c], 12[d]
Red. of Area, %				
As Rolled	47	43	21	19
Annealed	54	52	45	43
Hard. & Temp[a]	57[b]	50[b]	59[c], 50[d]	57[c], 48[d]
Hardness (Brinell)				
As Rolled	250	265	365	380
Annealed	185	195	230	240
Hard. & Temp[a]	320[b]	360[b]	300[c], 435[d]	310[c], 445[d]
Impact Str (Izod, hard. & temp[a]), ft-lb	40[b]	32[b]	75[c], 18[d]	73[c], 16[d]
FABRICATING PROPERTIES				
Annealing Temp, F	1550–1600	1550–1600	1550–1600	1550–1600
Hardening Temp, F	1525–1575	1525–1575	1475–1550	1475–1550
Max Hot Working Temp, F	2300	2300	2300	2300
Machinability Index[e]	55	51	51	51
Weldability	All grades readily weldable by oxyacetylene, inert arc and electrical resistance methods. Preheating desirable for AISI 4337 and 4340			
CORROSION RESISTANCE	Better corrosion resistance than plain carbon steels			
AVAILABLE FORMS	Usually supplied as bars, forgings, tubing and billets, but can be obtained in all steel mill forms			
USES	Heavy duty carburized parts such as gears, bearing races		Heavy duty, high strength applications, particularly in sections over about 1½ in. thick. Gears, aircraft tubing, shafts, heavy forgings, churn drills	

[a]Properties after heat treatment are based upon oil quench and 1-in. round bars.
[b]These are core properties of pseudo-carburized 1-in. bars, tempered at 300 F.
[c]Tempered at 1200 F. [d]Tempered at 800 F. [e]Based on AISI B1112 steel = 100.

Chromium-Vanadium Steels

AISI Type ➡	6120	6145	6150	6152
COMPOSITION, %	C 0.17–0.22, Mn 0.70–0.90, Si 0.20–0.35, Cr 0.70–0.90, V 0.10 min	C 0.43–0.48, Mn 0.70–0.90, Si 0.20–0.35, Cr 0.80–1.10, V 0.15 min	C 0.48–0.53, Mn 0.70–0.90, Si 0.20–0.35, Cr 0.80–1.10, V 0.15 min	C 0.48–0.53, Mn 0.70–0.90, Si 0.20–0.35, Cr 0.80–1.10, V 0.10 min
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.283	0.283	0.283	0.283
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.1×10^{-6}	8.1×10^{-6}	8.1×10^{-6}	8.1×10^{-6}
Spec Ht, Btu/lb/°F	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11
Elec Res (68 F), microhm-cm	21	21	21	21
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$
Ten Str, 1000 psi				
Normalized 1600 to 1650 F	85	115	158	—
Hard. & Tempered	105[a], 125[b]	176[c], 136[d]	187[c], 144[d]	151[e]
Yld Str, 1000 psi				
Normalized	50	75	88	—
Hard. & Temp	71[a], 94[b]	169[c], 130[d]	179[c], 138[d]	125[e]
Elong (in 2 in.), %				
Normalized	35	24	23	—
Hard. & Temp	19[a], 21[b]	16[c], 22[d]	13[c], 18[d]	16[e]
Red. of Area, %				
Normalized	67	64	62	—
Hard. & Temp	37[a], 56[b]	52[c], 58[d]	42[c], 53[d]	54[e]
Hardness (Brinell)				
Normalized	185	216	240	—
Hard. & Temp	—	429[c], 311[d]	444[c], 363[d]	—
Impact Str (Izod), ft-lb				
Normalized	102	31	—	—
Hard. & Temp	25[a], 28[b]	20[c], 87[d]	13[c], 63[d]	—
Fatigue Str	Endurance limit is proportional to tensile strength in the same ratio as in other low alloy steels. Below 400 Brinell, the ratio is about 50% and at higher hardnesses it is 45 to 48% of the tensile strength			
THERMAL TREATMENT				
Normalizing Temp, F	1650–1700	1600–1650	1600–1650	1600–1650
Hardening Temp, F	1600–1650	1550–1650	1550–1650	1550–1650
Tempering Temp, F	375–1200	450–1200	450–1200	450–1200
FABRICATING PROPERTIES				
Formability	Similar to other alloy steels of low chromium content. Hot working temperatures are limited not by brittle ranges but by degree of malleability required for the specific application. Because of stiffening, cold working is somewhat more difficult than with carbon steels			
Machinability Index[f]				
Hot Rolled	27	22	24	24
Normalized	46	27	26	26
Weldability	Weldable by all commercial welding procedures, the difficulty of welding increasing with carbon content. Preheating and postheating treatments sometimes necessary			
CORROSION RESISTANCE	Similar to carbon steels. Chromium content too low to have appreciable influence on rate of corrosion			
AVAILABLE FORMS	Available in all standard mill forms			
USES	Carburized gears, shafts, piston pins and bushings Nitrided and carbonitrided parts	Crankshafts, connecting rods, bevel and spur gears, shafts, springs, axles, pins		

[a]Typical core properties: carburized 16 hr at 1680 F, pot cooled, oil quenched from 1425 F, tempered at 300 F.
[b]Same as a but oil quenched from 1525 F.
[c]Normalized at 1600 F, oil quenched from 1575 F, tempered at 1000 F.
[d]Same as c but tempered at 1200 F.
[e]Oil quenched from 1575 F, tempered at 1000 F.
[f]Based on AISI B1112 steel = 100.

Nickel-Chromium-Molybdenum Steels (8600, 8700)

AISI Type →	8620, 8720	8630	8640, 8740	8650, 8750
COMPOSITION, %	C 0.18–0.23, Mn 0.70–0.90, Ni 0.40–0.70, Cr 0.40–0.60, Mo 0.15–0.25 (8620), 0.20–0.30 (8720)	C 0.28–0.33, Mn 0.70–0.90, Ni 0.40–0.70, Cr 0.40–0.60, Mo 0.15–0.25	C 0.38–0.43, Mn 0.75–1.00, Ni 0.40–0.70, Cr 0.40–0.60, Mo 0.15–0.25 (8640), 0.20–0.30 (8740)	C 0.48–0.53, Mn 0.75–1.00, Ni 0.40–0.70, Cr 0.40–0.60, Mo 0.15–0.25 (8650), 0.20–0.30 (8750)
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.283	0.283	0.283	0.283
Melting Point, F	2755	2750	2745	2745
Ther Cond (120 F), Btu/hr/sq ft/°F/ft	21.7	21.7	21.7	21.7
Coef of Ther Exp, per °F				
0 to 200 F	6.45×10^{-6}	6.45×10^{-6}	6.45×10^{-6}	6.45×10^{-6}
0 to 1200 F	8.25×10^{-6}	8.25×10^{-6}	8.25×10^{-6}	8.25×10^{-6}
Spec Ht, Btu/lb/°F	0.107	0.107	0.107	0.107
Elec Res, microhm-cm				
120 F	30	30	30	30
570 F	48	48	48	48
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$
Ten Str, 1000 psi				
Normalized	94	112	130	149
As Rolled	91	109	126	143
Annealed	77	86	95	105
Hard. & Temp (800 F)[a]	122, 96[b]	162, 111[b]	208, 130[b]	214, 136[b]
Yld Str, 1000 psi				
Normalized	61	73	85	96
As Rolled	65	78	90	101
Annealed	51	58	63	70
Hard. & Temp (800 F)[a]	98, 76[b]	142, 92[b]	183, 110[b]	194, 116[b]
Elong (in 2 in.), %				
Normalized	29	23	18	11
As Rolled	29	25	20	17
Annealed	32	29	27	23
Hard. & Temp (800 F)[a]	21, 26[b]	14, 23[b]	13, 21[b]	12, 21[b]
Red. of Area, %				
Normalized	61	52	45	36
As Rolled	56	48	40	31
Annealed	64	59	55	50
Hard. & Temp (800 F)[a]	63, 70[b]	54, 66[b]	43, 60[b]	41, 61[b]
Hardness (Brinell)				
Normalized	190	225	262	300
As Rolled	185	220	244	290
Annealed	163	174	193	210
Hard. & Temp (800 F)[a]	245, 193[b]	325, 225[b]	420, 262[b]	423, 271[b]
Impact Str (Izod, hard. & temp at 800 F), ft-lb[a]	76, 105[b]	42, 91[b]	18, 68[b]	—
FABRICATING PROPERTIES				
Annealing Temp, F	1550–1600	1550–1600	1550–1600	1550–1600
Hardening Temp, F	1525–1575	1525–1575	1500–1550	1475–1550
Max Hot Working Temp, F	2200	2200	2200	2150
Machinability Index[c]	57[d]	61[e]	55[e]	45[e]
Weldability	Readily weldable by oxyacetylene, inert arc and electrical resistance methods. Preheating desirable for grades with more than 0.30% carbon content			
CORROSION RESISTANCE	Better corrosion resistance than plain carbon steels			
AVAILABLE FORMS	Usually supplied as bars, forgings, tubing or billets; sometimes in other steel mill forms			
USES	Medium duty carburized parts such as gears, cams, bearing races		Medium duty, high strength applications, particularly in sections not over approx 2 in. thick. Gears, bolts, aircraft tubing, hand tools, shafts, forgings	

[a]Properties after heat treatment are based upon an oil quench and 1-in. round bars. [b]Tempered at 1200 F.
[c]Based on AISI B1112 steel = 100. [d]As rolled. [e]Annealed.

Manganese-Silicon and Manganese-Nickel-Chromium-Molybdenum Steels

AISI Type ➡	9255	9261	9440	9450
COMPOSITION, %	C 0.50–0.60, Mn 0.70–0.95, Si 1.80–2.20	C 0.55–0.65, Mn 0.75–1.00, Si 1.80–2 20, Cr 0.10–0.25	C 0.38–0.43, Mn 0.90–1.20, Si 0.20–0.35, Ni 0.30–0.60, Cr 0.30–0.50, Mo 0.08–0.15	C 0.43–0.48, Mn 1.00–1.30, Si 0.20–0.35, Ni 0.30–0.60, Cr 0.30–0.50, Mo 0.08–0.15
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.283	0.283	0.283	0.283
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.1×10^{-6}	8.1×10^{-6}	8.1×10^{-6}	8.1×10^{-6}
Spec Ht, Btu/lb/°F	0.10–0.11	0.10–0.11	0.11–0.12	0.11–0.12
Elec Res (68 F), microhm-cm	19	20	20	20
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	29×10^6	29×10^6	29×10^6	29×10^6
Ten Str, 1000 psi				
Normalized	132[a]	150[c]	115[e]	158[e]
Hard. & Temp (800 F)	232[b]	258[d]	192[f]	210[g]
Hard. & Temp (1200 F)	144[b]	148[d]	120[f]	132[g]
Yld Str, 1000 psi				
Normalized	90	80	74	110
Hard. & Temp (800 F)	215	226	179	192
Hard. & Temp (1200 F)	118	125	102	120
Elong (in 2 in.), %				
Normalized	18	15	24	15
Hard. & Temp (800 F)	9	10	15	12
Hard. & Temp (1200 F)	20	18	23	20
Red. of Area, %				
Normalized	38	30	50	30
Hard. & Temp (800 F)	21	30	56	48
Hard. & Temp (1200 F)	42	40	67	57
Hardness (Brinell)				
Normalized	277	311	235	331
Hard. & Temp (800 F)	477	514	388	429
Hard. & Temp (1200 F)	285	311	248	285
Impact Str (Izod), ft-lb				
Normalized	12	5	48	8
Hard. & Temp (800 F)	6	12	35	14
Hard. & Temp (1200 F)	22	35	99	72
THERMAL TREATMENT				
Normalizing Temp, F	1625–1675	1600–1650	1575–1625	1575–1625
Hardening Temp, F	1500–1650	1500–1650	1500–1550	1500–1550
FABRICATING PROPERTIES				
Hot Working Temp Range, F	1750–2175	1750–2175	1750–2175	1750–2175
Machinability Index (AISI B1112 steel = 100)	38	36	42	40
Weldability	Welding not normally recommended because high carbon and silicon contents introduce difficulty		High carbon content introduces difficulty in welding. With special techniques and electrodes, satisfactory arc welds can be made	
CORROSION RESISTANCE	Better than plain carbon steels in industrial atmosphere and about the same when continuously exposed to moisture. If salts are present, corrosion is increased. Attacked readily by acids, but resistant to alkalis at ordinary temperatures			
AVAILABLE FORMS	Billets, bars, forgings			
USES	Coil and flat springs, lock washers, axes, chisels, hand tools, diesel engine connecting rod bolts, collets for machine tools		Not in general use today. Formerly used for automotive, diesel engine and aircraft parts; bolts; chain; gears	

[a]Normalized at 1650 F. [b]Normalized at 1650 F, reheated to 1625 F, quenched in agitated oil.
[c]Normalized at 1600 F. [d]Normalized at 1600 F, reheated to 1575 F, quenched in agitated oil.
[e]Normalized at 1600 F. [f]Normalized at 1600 F, reheated to 1525 F, quenched in agitated oil.
[g]Normalized at 1600 F, reheated to 1500 F, quenched in agitated oil.

Austenitic Stainless Steels

AISI Type →	301	302	303	304 , 304 ELC
COMPOSITION, %	C 0.08–0.20, Mn 2 max, Si 1 max, P 0.04 max, S 0.03 max, Cr 16–18, Ni 6–8	C 0.08–0.20, Mn 2 max, Si 1 max, P 0.04 max, S 0.03 max, Cr 17–19, Ni 8–10	C 0.15 max, Mn 2 max, P, S or Se 0.07 min, Si 1 max, Cr 17–19, Ni 8–10, Mo or Zr 0.60 max	C 0.08 max (304) or 0.03 max (304 ELC), Mn 2 max, Si 1 max, P 0.04 max, S 0.030 max, Cr 18–20, Ni 8–11
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.29	0.29	0.29	0.29
Melting Point Range, F	2550–2590	2550–2590	2550–2590	2550–2650
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	9.4	9.4	9.4	9.4
Coef of Ther Exp (32–212 F), per °F	9.5 x 10^{-6} [a]	9.9 x 10^{-6}	9.9 x 10^{-6}	9.9 x 10^{-6}
Spec Ht (32–212 F), Btu/lb/°F	0.12	0.12	0.12	0.12
Elec Res (68 F), microhm-cm	72	72	72	72 (70 F)
MECHANICAL PROPERTIES [b]				
Mod of Elast in Tension, psi	28.0 x 10^6	28.0 x 10^6	28.0 x 10^6	28.0 x 10^6
Ten Str, 1000 psi				
Annealed	110, 105, —	90, 90, 85	—, —, 90	85, 85, 85
Cold Worked [d]	185, —, —	—, —, 110 [c]	—, —, 110 [c]	—, —, 110 [c]
Yld Str, 1000 psi				
Annealed	40, 40, —	40, 35, 35	—, —, 35	35, 30, 35
Cold Worked [d]	140, —, —	—, —, 75 [c]	—, —, 75 [c]	—, —, 75 [c]
Elong (in 2 in.), %				
Annealed	60, 55, —	50, 60, 60	—, —, 50	50, 60, 60
Cold Worked [d]	8–9, —, —	—, —, 35 [c]	—, —, 30 [c]	—, —, 60
Red. of Area, %				
Annealed	—, 70, —	—, 70, 70	—, —, 55	—, 70, 70
Cold Worked	—	—, —, 60 [c]	—, —, 50 [c]	—
Hardness [e]				
Annealed	R_B85, —, —	R_B85, R_B80, 150	—, —, 160	R_B80, 150, 150
Cold Worked	R_B41, —, —	—, —, 240 [c]	—, —, 240 [c]	—, —, 240 [c]
Impact Str (Izod), ft-lb				
Annealed	—, 165, —	—, 110, 110	—, —, 80	—, 110, 110
Cold Worked	—	—	—	—, —, 90 [c]
Endurance Limit, 1000 psi				
Annealed	35, 39, —	—, —, 34	—, —, 35	35, 35, 34
Cold Worked	80, —, —	—	—	—
Creep Str (1% ext in 1000 hr), psi				
1000 F	—	17,000	—	17,000
1300 F	—	4,000	—	4,000
1500 F	—	1,200	—	1,200
FABRICATING PROPERTIES				
Annealing Temp, F [f]	1850–2050	1900–2050	1850–2050	1900–2050
Forging Temp (start), F [g]	2200	2100	2100	2200
Machinability	—	Fair; tough	Good; about 65% of screw stock	Fair; tough
Weldability	Very good	Not recommended; may crack		Very good
CORROSION RESISTANCE	Very good atmosphere resistance; slightly less than type 302	Excellent atmosphere resistance; also resists food products, acids and other chemicals	Very good atmosphere resistance; some resistance sacrificed for better machinability	Excellent atmosphere resistance; slightly better than type 302
AVAILABLE FORMS	Sheet, strip, wire	Sheet, strip, plate, bar, wire	Bar, wire	Sheet, strip, plate, bar, wire
USES	Lightweight, high strength applications; transportation equipment, roof drainage and trim	General purpose	General purpose, but where better machinability (than type 302) is required	Light welded construction where corrosive conditions are not too severe

[a]For 32-600 F range. [b]Where three values are given, they represent sheet, plate and bar in that order.
[c]Cold drawn, high tensile 1½-in. dia bar. [d]Minimum value at full hard temper.
[e]Values are Brinell except where Rockwell scale is noted. [f]Cool rapidly after anneal.
[g]Finish forging all grades at 1700 F or above.

Austenitic Stainless Steels—concluded

AISI Type ➡	309	316, 316 ELC	321
COMPOSITION, %	C 0.20 max, Mn 2 max, P 0.04 max, S 0.03 max, Si 1 max, Cr 22–24, Ni 12–15	C 0.10 max (316), C 0.03 max (316 ELC), Mn 2 max, Si 1 max, P 0.04 max, S 0.03 max, Cr 16–18, Ni 10–14, Mo 2–3	C 0.08 max, Mn 2 max, Si 1 max, P 0.04 max, S 0.03 max, Cr 17–19, Ni 8–11, Ti 5 x C
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.29	0.29	0.29
Melting Point Range, F	2550–2650	2500–2550	2550–2600
Thermal Conductivity (212 F), Btu/hr/sq ft/°F/ft	8	9.4	9.3
Coef of Ther Exp (32–600 F), per °F	9.3 x 10^{-6}	9.0 x 10^{-6}	9.5 x 10^{-6}
Specific Heat (32–212 F), Btu/lb/°F	0.12	0.12	0.12
Electrical Resistivity (68 F), microhm-cm	78	74	72 (70 F)
MECHANICAL PROPERTIES[a]			
Mod of Elast in Tension, psi	29.0 x 10^6	28.0 x 10^6	28.0 x 10^6
Tensile Strength (annealed), 1000 psi	90, 95, 95	90, 85, 80	90, 85, 85
Yield Strength (annealed), 1000 psi	45, 40, 40	40, 35, 30	35, 30, 35
Elongation (in 2 in., annealed), %	45, 45, 45	50, 55, 60	50, 55, 55
Reduction of Area (annealed), %	—, —, 65	—, —, 70	—, —, 65
Hardness (annealed)[b]	R_B85, 170, 160	R_B85, 150, 150	R_B80, 160, 150
Impact Strength (Izod, annealed), ft-lb	—, —, 110	—, —, 110	—, —, 110
Endurance Limit (annealed), 1000 psi	—	39, 39, 38	—, —, 38
Creep Strength (1% ext in 10,000 hr), psi			
1000 F	15,900	25,000	18,000
1300 F	4,500	7,900	4,500
1500 F	1,000	2,800	850
FABRICATING PROPERTIES			
Annealing Temp, F	1900–2050	1850–2050	1900–2050
Forging Temp (start), F[c]	2150	2200	2250
Machinability	Fair; tough	Fair; tough	Fair; tough
Weldability	Good	Very good	Very good
CORROSION RESISTANCE	Excellent atmosphere resistance; better than type 302. Resists destructive heat scaling up to 2000 F	Best of any standard stainless steel. Greater resistance than type 302 to reducing acids, sea water and other corrosive media causing pitting type of corrosion. Intergranular corrosion due to welding eliminated in 316 ELC	Excellent atmosphere resistance; similar type 302. Not subject to harmful carbide precipitation
AVAILABLE FORMS	Sheet, strip, plate, bar, wire	Sheet, strip, plate, bar, wire	Sheet, strip, plate, bar, wire
USES	Heat resisting applications	Processing equipment exposed to severe corrosive media. Stressed parts that operate at high temperatures	Welded equipment used in the unannealed condition and exposed to corrosive conditions. Equipment that must operate in the sensitization range (800–1650 F)

[a] Where three values are given, they represent sheet, plate and bar in that order.
[b] Values for sheet are Rockwell; values for plate and bar are Brinell.
[c] Finish forging all grades at 1700 F or above.

Martensitic Stainless Steels

AISI Type →	403, 410	414	416	420	431
COMPOSITION, %	C 0.15 max, Cr 11.5–13.5	C 0.15 max, Cr 11.5–13.0, Ni 1.25–2.5	C 0.15 max, Cr 12–14, P, S or Se 0.07 min, Mo or Zr 0.06 max	C > 0.15, Cr 12–14	C 0.20 max, Cr 15–17, Ni 1.25–2.50
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.28	0.28	0.28	0.28	0.28
Melting Point, F	2700–2790	—	2700–2790	2650–2750	2650
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	14.4	14.4	14.4	14.4	11.7
Coef of Ther Exp, per °F					
32–212 F	5.5×10^{-6}	5.8×10^{-6}	5.5×10^{-6}	5.7×10^{-6}	6.5×10^{-6}
32-1200 F	6.5×10^{-6}	—	6.5×10^{-6}	6.8×10^{-6}	—
Spec Ht (32–212 F), Btu/lb/°F	0.11	0.11	0.11	0.11	0.11
Elec Res (rm temp), microhm-cm	57	70	57	55	72
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES					
Ten Str, 1000 psi					
Annealed	65–75	115–120	75	95	125
Hard. & Temp.	90–190	120–200	90–190	230	125–205
Yld Str 1000 psi					
Annealed	35–50	90–105	40	50	95
Hard. & Temp.	60–145	105–150	60–145	195	90–155
Mod of Elast in Tension, 1000 psi	29.0×10^6	29.0×10^6	29.0×10^6	29.0×10^6	29.0×10^6
Elong (in 2 in.), %					
Annealed	25–35	15–20	30	25	20
Hard. & Temp.	15–30	15–20	12–25	8	15–20
Hardness (Brinell)					
Annealed	155	235	155	195	260
Hard. & Temp.	180–390	250–410	180–390	500	260–415
Impact Str (Izod), ft-lb					
Annealed	90	50	70	—	—
Hard. & Temp.	35–75	45–50	20–60	10	30–50
Endurance Limit (annealed), 1000 psi	40	45	40	40	45
Creep Str (1% ext in 10,000 hr, annealed), psi					
1000 F	9200	—	9200	—	—
1300 F	1000	—	1000	—	—
THERMAL TREATMENT					
Annealing Temp, F	1500–1650	—	1500–1650	1550–1650	—
Hardening Temp, F	1700–1850	1800–1900	1700–1850	1800–1900	1800–1950
Tempering Temp, F	400–1400	400–1300	400–1400	300–700	400–1200
FABRICATING PROPERTIES					
Machinability	Fair	Poor	Good; 80% of screw stock	Fair	Poor
Weldability	Fair; small welds can be annealed	Poor	Poor	Fair	Poor
Forging Temp (start), F	2000–2200	2100–2200	2100–2300	2000–2200	2100–2250
CORROSION RESISTANCE	Good resistance to weather and water; also good resistance to some chemicals				
AVAILABLE FORMS	Plate, sheet, strip. bar, tube, rounds, structural and bar shapes, round and flat wire, tubing				
USES	Steam turbine blades, highly stressed parts	Springs, knife blades, tempered rules	Automatic screw machine parts	Cutlery, surgical instruments, ball bearings, magnets	High strength parts

Martensitic Stainless Steels—concluded

AISI Type →	440A	440B	440C	501	502
COMPOSITION, %	C 0.60–0.75, Cr 16–18, Mo 0.75 max	C 0.75–0.95, Cr 16–18, Mo 0.75 max	C 0.95–1.20, Cr 16–18, Mo 0.75 max	C > 0.10, Cr 4–6	C 0.10 max, Cr 4-6
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.28	0.28	0.28	0.28	0.28
Melting Point, F	2500–2750	2500–2750	2500–2750	2700–2800	2700–2800
Ther Cond (212 F), Btu/hr/sq ft/°F/ft.	14.0	14.0	14.0	21.2	21.2
Coef of Ther Exp, per °F					
32–212 F	5.6×10^{-6}	5.6×10^{-6}	5.6×10^{-6}	6.2×10^{-6}	6.2×10^{-6}
32–1200 F	—	—	—	7.3×10^{-6}	7.3×10^{-6}
Spec Ht (32–212 F), Btu/lb/°F	0.11	0.11	0.11	0.11	0.11
Elec Res (rm temp), microhm-cm	60	60	60	40	40
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES					
Mod of Elast in Tension, 1000 psi	29.0×10^6	29.0×10^6	29.0×10^6	29.0×10^6	29.0×10^6
Ten Str, 1000 psi					
Annealed	105	107	110	70	65–70
Hard. & Temp	260	280	285	115–175	—
Yld Str, 1000 psi					
Annealed	60	62	65	30	25–30
Hard. & Temp	240	270	275	90–135	—
Elong (in 2 in.), %					
Annealed	20	18	14	28	30
Hard. & Temp	5	3	2	15–20	—
Hardness (Brinell)					
Annealed	215	220	230	160	150
Hard. & Temp	510	555	580	240–370	—
Impact Str (Izod), ft-lb					
Annealed	2	2	2	—	85
Hard. & Temp	4	3	2	—	—
Endurance Limit (annealed), 1000 psi	40	40	40	35	35
Creep Str (1% ext in 10,000 hr, annealed), psi					
1000 F	Not used in fatigue applications			9500	9500
1300 F				800	800
THERMAL TREATMENT					
Annealing Temp, F	1550–1650	1550–1650	1550–1650	1525–1600	1525–1600
Hardening Temp, F	1850–1950	1850–1950	1850–1950	1600–1700	—[a]
Tempering Temp, F	300–800	300–800	300–800	400–1400	—[a]
FABRICATING PROPERTIES					
Machinability	Fair	Fair	Fair	—	—
Weldability	Welding not generally recommended	Welding not generally recommended	Welding not recommended	—	—
Forging Temp (start), F	1900–2200	1900–2150	1900–2100	—	—
CORROSION RESISTANCE	Good resistance to weather and water; also good resistance to some chemicals				
AVAILABLE FORMS	Plate, sheet, strip, bar, tube, rounds, structural and bar shapes, round and flat wire, and tubing				
USES	Instruments, cutlery, valves			Applications requiring heat resistance and good mechanical properties at elevated temperatures	

[a]Generally used in annealed condition only.

Cast Carbon Steels

Class[a] →	60,000	65,000	70,000	80,000	85,000	100,000
PHYSICAL PROPERTIES						
Density, lb/cu in.	0.283	0.283	0.283	0.283	0.283	0.283
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.3×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.3×10^{-6}	8.3×10^{-6}
Spec Ht, Btu/lb/°F	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11
Elec Res (68 F), microhm-cm	13–16	13–16	13–16	13–16	13–16	13–16
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES[b]						
Mod of Elast in Tension, psi	30.1×10^6	30.1×10^6	30×10^6	29.9×10^6	29.9×10^6	29.7×10^6
Ten Str, 1000 psi	60[c]	65[d]	70[d]	80[e]	85[e]	100[f]
Yld Point, 1000 psi	30[c]	35[d]	38[d]	45[e]	50[e]	70[f]
Elong (in 2 in.), %	32[c]	30[d]	28[d]	26[e]	24[e]	20[f]
Red. of Area, %	55[c]	53[d]	50[d]	43[e]	40[e]	46[f]
Hardness (Brinell)	120[c]	130[d]	140[d]	160[e]	175[e]	200[f]
Impact Str (Izod), ft-lb						
70 F	30[c]	30[d]	30[d]	25[e]	20[e]	30[f]
−50 F	8[c]	12[d]	10[d]	12[e]	10[e]	15[f]
Endurance Limit, 1000 psi	25[c]	28[d]	31[d]	35[e]	38[e]	47[f]
THERMAL TREATMENT						
Annealing Temp, F	About 200 F above critical range					
Quenching Temp, F	About 100 F above critical range					
FABRICATING PROPERTIES						
Machinability Index[g]	55	60	65	70	70	65
Weldability	Can be welded by procedures used for welding wrought steels of similar composition					
CORROSION RESISTANCE	When brought into contact with moisture and air, carbon steels rust at rates that are not affected by carbon content. If salts are present, corrosion rate is increased. Attacked readily by acids, but resistant to alkalis at ordinary temperatures					
USES	Applications requiring low electrical resistivity, good magnetic properties, carburizing and case hardening, weldability	Applications requiring excellent weldability; medium strength with good machinability and high ductility	Applications requiring high strength with good machinability, toughness and excellent fatigue resistance	Applications requiring wear resistance and hardness		

[a]Tensile strength, psi.
[b]Normally expected values for steel castings having tensile strength given.
[c]Annealed.
[d]Normalized.
[e]Normalized and tempered.
[f]Quenched and tempered.
[g]Based on AISI B1112 steel = 100.

Cast Low Alloy Steels[a]

Class[b] →	70,000	80,000	90,000	100,000	110,000
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.283	0.283	0.283	0.283	0.283
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.0–8.3 x 10^{-6}	8.0–8.3 x 10^{-6}	8.0–8.3 x 10^{-6}	8.0–8.3 x 10^{-6}	8.0–8.3 x 10^{-6}
Spec Ht, Btu/lb/°F	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11
Elec Res (68 F), microhm-cm	15–20	15–20	15–20	15–20	15–20
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES[c]					
Mod of Elast in Tension, psi	29–30 x 10^6	29–30 x 10^6	29–30 x 10^6	29–30 x 10^6	29–30 x 10^6
Ten Str, 1000 psi	70[e]	80[e]	90[e]	100[e]	110[f]
Yld Point, 1000 psi	45	50	60	68	85
Elong (in 2 in.), %	26	24	22	20	20
Red. of Area, %	56	50	46	42	45
Hardness (Brinell)	150	170	190	209	235
Impact Str (Charpy), ft-lb					
70 F	35	30	26	22	23
–50 F	25	20	15	12	18
Endurance limit, 1000 psi	33	38	41	45	49
THERMAL TREATMENT					
Annealing Temp, F	About 200 F above critical range				
Quenching Temp, F	About 100 F above critical range				
FABRICATING PROPERTIES					
Machinability Index[d]	65	70	70	65	60
Weldability	Can be welded by procedures used for wrought steels of similar composition				
CORROSION RESISTANCE	Similar to corrosion resistance of carbon steels				
USES	Applications requiring excellent weldability; medium strength with high toughness and good machinability; good high temperature properties		Applications requiring toughness or excellent high temperature and deep hardening properties		Applications requiring high resistance to impact; excellent low temperature properties; deep hardening; or excellent combination of strength and toughness

[a]Below 8% total alloy content.
[b]Tensile strength, psi.
[c]Normally expected values for steel castings having tensile strength given.
[d]Based on AISI B1112 steel = 100.
[e]Normalized and tempered.
[f]Quenched and tempered.

continued

Cast Low Alloy Steels—concluded

Class[b] →	120,000	150,000	175,000	200,000
PHYSICAL PROPERTIES				
Density, lb/cu in	0.283	0.283	0.283	0.283
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	27	27	27	27
Coef of Ther Exp (70–1200 F), per °F	8.0–8.3 x 10^{-6}	8.0–8.3 x 10^{-6}	8.0–8.3 x 10^{-6}	8.0–8.3 x 10^{-6}
Specific Heat, Btu/lb/°F	0.10–0.11	0.10–0.11	0.10–0.11	0.10–0.11
Elec Res (68 F), microhm-cm	15–20	15–20	15–20	15–20
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES[c]				
Mod of Elast in Tension, psi	29–30 x 10^6	29–30 x 10^6	29–30 x 10^6	29–30 x 10^6
Ten Str, 1000 psi	120[f]	150[f]	175[f]	200[f]
Yld Point, 1000 psi	95	125	148	170
Elong. (in 2 in.), %	16	12	8	5
Red. of Area, %	38	25	20	11
Hardness (Brinell)	245	300	340	400
Impact Str (Charpy), ft-lb				
70 F	20	14	10	—
–50 F	16	10	6	—
Endurance Limit, 1000 psi	55	65	77	85
THERMAL TREATMENT				
Annealing Temp, F	About 200 F above critical range			
Quenching Temp, F	About 100 F above critical range			
FABRICATING PROPERTIES				
Machinability Index[d]	50	30	—	—
Weldability	Can be welded by procedures used for wrought steels of similar composition			
CORROSION RESISTANCE	Generally similar to carbon steels			
USES	Applications requiring high resistance to impact, excellent low temperature properties, deep hardening; excellent combination of strength and toughness	Applications requiring deep hardening, high strength, wear resistance, fatigue resistance	Applications requiring high strength, wear resistance, high hardness, high fatigue resistance	

[a]Below 8% total alloy content.
[b]Tensile strength, psi.
[c]Normally expected values for steel castings having tensile strength given.
[d]Based on AISI B1112 steel = 100.
[f]Quenched and tempered.

Cast Stainless Steels

ACI Type →	CA-15	CA-40	CB-30	CC-50
COMPOSITION, %	Cr 11.5–14.0, Ni 1.0 max, C 0.15 max, Mn 1.0 max, Si 1.5 max	Cr 11.5–14.0, Ni 1.0 max, C 0.20–0.40, Mn 1.00 max, Si 1.50 max	Cr 18–22, Ni 2.0 max, C 0.30 max, Mn 1.00 max, Si 1.00 max	Cr 26–30, Ni 4.0 max, C 0.50 max, Mn 1.0 max, Si 1.0 max
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.275	0.275	0.272	0.272
Melting Point, F	2750	2725	2725	2725
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	14.5	14.5	12.8	12.6
Coef of Ther Exp (70–1000 F), per °F	6.4×10^{-6}	6.4×10^{-6}	6.5×10^{-6}	6.4×10^{-6}
Spec Ht (70 F), Btu/lb/°F	0.11	0.11	0.11	0.12
Elec Res (70 F), microhm-cm	78	76	76	77
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	29×10^6	29×10^6	29×10^6	29×10^6
Ten Str, 1000 psi				
Annealed	—	—	95[d]	97[e]
As Cast	—	—	—	70–95
Hard. & Temp	200[a], 100[b]	220[a], 110[c]	—	—
Yld Str (0.2% offset), 1000 psi				
Annealed	—	—	60[d]	65[e]
As Cast	—	—	—	60–65
Hard. & Temp	150[a], 75[b]	165[a], 67[c]	—	—
Elong (in 2 in.), %				
Annealed	—	—	15[d]	18[e]
As Cast	—	—	—	2–15
Hard. & Temp	7[a], 30[b]	1[a], 18[c]	—	—
Hardness (Brinell)				
Annealed	—	—	195[d]	210[e]
As Cast	—	—	—	193–212
Hard. & Temp	390[a], 185[b]	470[a], 212[c]	—	—
Impact Str (Charpy, keyhole notch), ft-lb				
Annealed	—	—	2[d]	—
As Cast	—	—	—	2–45 (Izod V notch)
Hard. & Temp	15[a], 35[b]	1[a], 3[c]	—	—
THERMAL TREATMENT				
Annealing Temp, F[f]	1450–1650 f.c.	1450–1650 f.c.	1450 f.c. and 1000 a.c.	1450 f.c. or a.c.
Hardening Temp, F[f]	1800–1850 a.c. or o.q.	1800–1850 a.c. or o.q.	Practically nonhardenable by heat treatment	Nonhardenable by heat treatment
Tempering Temp, F	< 600 or 1100–1500. Highest strength by tempering below 600		—	—
FABRICATING PROPERTIES				
Castability	Section thicknesses from 3/16 in. up can be cast satisfactorily. Somewhat lighter sections can be cast in some parts. Difficult-to-run thin sections and designs involving appreciable changes in section should be avoided. Normal shrinkage for these alloys is 1/4 in. per ft, except CC-50 which shrinks 7/32 in. per ft			
Weldability	Can be welded by metal arc, inert-gas-arc and oxyacetylene gas methods. Metal arc most frequently used. Oxyacetylene welding not advisable because of possible reduction in corrosion resistance resulting from carbon pick-up. Castings should be preheated and postheated			
CORROSION RESISTANCE	Good atmospheric corrosion resistance. Excellent resistance to many organic media in relatively mild service		Resists nitric acid, alkaline solutions, many organic chemicals, oxidizing atmospheres up to 1400 F	Excellent resistance to dilute sulfuric acid in mine waters, mixed nitric and sulfuric acids, and oxidizing acids of all types
USES	Pumpcasings, bushings and liners, impellers, shafts, turbine blades, stuffing boxes, valve bodies and trim, furnace burner tips	Choppers, cutting blades, cylinder liners, pump parts, steam turbine parts, molds and dies	Furnace brackets and hangers, pump parts, rabble arms, tube supports, valve bodies and parts	Bushings, cylinder liners, pump casings and impellers, valve bodies and seats

[a]Air cooled from 1800 F, tempered at 600 F.
[b]Air cooled from 1800 F, tempered at 1450 F.
[c]Air cooled from 1800 F, tempered at 1400 F.
[d]Annealed at 1450 F, furnace cooled to 1000 F, air cooled.
[e]Air cooled from 1900 F.
[f]f.c. = furnace cool, a.c. = air cool, o.q. = oil quench.

continued

Cast Stainless Steels—continued

ACI Type ➡	CE-30	CF-8	CF-20	CF-8M, CF-12M	CF-8C
COMPOSITION, %	Cr 26–30, Ni 8–11, C 0.30 max, Mn 1.50 max, Si 2.00 max	Cr 18–21, Ni 8–11, C 0.08 max, Mn 1.50 max, Si 2.00 max	Cr 18–21, Ni 8–11, C 0.20 max, Mn 1.50 max, Si 2.00 max	Cr 18–21, Ni 9–12, Mo 2.0–3.0, C 0.08 (CF-8M) or 0.12 (CF-12M), Mn 1.50 max, Si 2.00 max	Cr 18–21, Ni 9–12, Cb 1.0 max[j], C 0.08 max, Mn 1.50 max, Si 2.00 max
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.277	0.280	0.280	0.280	0.280
Melting Point, F	2650	2600	2575	2550	2600
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	—	9.2	9.2	9.4	9.3
Coef of Ther Exp (70–1000 F), per °F	9.6×10^{-6}	10.0×10^{-6}	10.4×10^{-6}	9.7×10^{-6}	10.3×10^{-6}
Spec Ht (70 F), Btu/lb/°F	0.14	0.12	0.12	0.12	0.12
Elec Res (70 F), microhm-cm	85	76	78	82	71
Magnetic Permeability	>1.5	1.0–1.3[g]	1.01	1.50–2.50	1.20–1.80
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	25×10^6	28×10^6	28×10^6	28×10^6	28×10^6
Ten Str, 1000 psi					
As Cast	95	—	—	—	—
Water Quenched[h]	97	77	77	80	77
Yld Str (0.2% offset), 1000 psi					
As Cast	60	—	—	—	—
Water Quenched[h]	63	37	36	42	38
Elongation (in 2 in.), %					
As Cast	15	—	—	—	—
Water Quenched[h]	18	55	50	50	39
Hardness (Brinell)					
As Cast	170	—	—	—	—
Water Quenched[h]	170	140	163	156–170	149
Impact Str (Charpy keyhole notch, water quenched[h]), ft-lb	—	74	60	70	30
FABRICATING PROPERTIES					
Castability	Section thicknesses from 3/16 in. up can be cast satisfactorily. Somewhat lighter sections are also possible in some parts. Good castability of these alloys permits designs involving intricate shapes, but drastic changes in section should be avoided and uniform thickness should be maintained as far as possible				
Quenching Temp, F[i]	1950–2050	1950–2050	2000–2100	1950–2100	1950–2050
Weldability	Can be welded by metal arc, inert-gas arc and oxyacetylene gas methods. Metal arc most frequently used. Oxyacetylene welding not advisable because of possible reduction in corrosion resistance caused, by carbon pick-up. Preheating not necessary, but castings should be quenched from the range 1950 to 2100 F to restore maximum corrosion resistance. This heat treatment is not always necessary, however with CE-30 and CF-8C alloys				
CORROSION RESISTANCE	Particularly resistant to sulfurous acid, mixtures of dilute sulfuric and sulfurous acids, sulfuric and nitric acids, and sulfites	Resists strongly oxidizing media such as boiling nitric acid, sulfuric acid and sulfates, and organic acids	Similar to CF-8 but used under less drastic conditions	Resists reducing media. More resistant to pitting corrosion than CF-8 in contact with chlorides. Not as resistant to boiling nitric acid as CF-8	Similar to CF-8
USES	Process equipment such as digester fittings, fractionating towers, piping, pump bodies and casings, valve bodies and parts	Autoclaves, blast furnaces, bushings, filter press plates, hardware, headers and heating coils, pump parts, spray nozzles, valve parts	Cylinder liners, pumps, return bends, rolls, circuit breaker parts, valve parts	Agitators, evaporator parts, jet engine components, spray nozzles, high pressure steam valves	Aircraft shroud assemblies, autoclaves, chemical tubing, fittings, jet engine parts, marine fittings

[g]After heat treatment.
[h]Water quenched from 2000 F.
[i]Water, oil or air quench.
[j]Minimum is eight times carbon content.

Cast Stainless Steels—concluded

ACI Type ➡	CF-16F	CH-20	CK-20	CN-7M
COMPOSITION, %	Cr 18–21, Ni 9–12, C 0.16 max, Mo 1.50 max, Se 0.20–0.35, Mn 1.50 max, Si 2.00 max	Cr 22–26, Ni 12–15, C 0.20 max, Mn 1.50 max, Si 2.00 max	Cr 23–27, Ni 19–22, C 0.20 max, Mn 1.50 max, Si 2.00 max	Cr 19–22, Ni 27.5–30.5, Mo 1.75–2.50, Cu 3.00 min, C 0.07 max, Mn 1.50 max, Si 1.50 max
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.280	0.279	0.280	0.289
Melting Point, F	2550	2600	2600	2650
Thermal Cond (212 F), Btu/hr/sq ft/°F/ft	9.4	8.2	8.2	12.1
Coef of Ther Exp (70–1000 F), per °F	9.9×10^{-6}	9.6×10^{-6}	9.2×10^{-6}	9.7×10^{-6}
Specific Ht (70 F), Btu/lb/°F	0.12	0.12	0.12	0.11
Elect Res (70 F), microhm-cm	72	84	90	90
Magnetic Permeability	1.0–2.0	1.71[g]	1.02	1.01–1.10
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	28×10^6	28×10^6	29×10^6	24×10^6
Ten Str, 1000 psi[h]	77	88	76	69
Yld Str (0.2% offset), 1000 psi[h]	40	50	38	31.5,
Elong (in 2 in), %[h]	52	38	37	48
Hardness (Brinell)[h]	150	190	144	130
Impact Str (Charpy, keyhole notch), ft-lb[h]	75	30	46 (Izod V notch)	70
FABRICATING PROPERTIES				
Castability	Section thicknesses from 3/16 in. up can be cast satisfactorily. Somewhat lighter sections are also possible on some parts. Good castability permits designs involving intricate shapes, but drastic changes in section should be avoided			
Quenching Temp, F[i]	2000–2100	2000–2100	2000–2150	1950–2050
Weldability	Can be welded by metal arc, inert-gas-arc, and oxyacetylene gas methods. Metal arc welding most used. Oxyacetylene welding not advisable because of possible reduction in corrosion resistance resulting from carbon pick-up			
	Preheating not necessary, but castings should be quenched from 2000–2100 F to restore maximum corrosion resistance			Preheating at 400 F necessary. After welding, castings should be quenched from 2000 F
CORROSION RESISTANCE	Similar to but somewhat inferior to CF–8	Resistant to hot dilute sulfuric acid. Superior to CF–8 in certain media	Similar to CH-20, but better resistance at elevated temperatures	Resists sulfuric acid and many reducing chemicals. Good resistance to dilute hydrochloric acid and salt solutions
USES	Bearings, bushings, fittings, pump and machinery parts	Digester fittings, roasting equipment, valves, pump parts	Digesters, filter press parts, fittings, jet engine parts, pumps, valves	Filter parts; heat exchanger parts; pickling rolls, hooks, racks and tanks; valve parts

[g]After heat treatment.
[h]Water quenched from 2000 F.
[i]Water, oil or air quench.

Cast Heat Resistant Alloys

ACI Type →	HA	HC	HD	HE	HF
COMPOSITION, %	C 0.20 max, Mn 0.35-0.65, Si 1.00 max, P 0.04 max, S 0.04 max, Mo 0.90-1.20, Cr 8-10	C 0.50 max, Mn 1.00 max, Si 2.00 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 26-30, Ni 4 max	C 0.50 max, Mn 1.50 max, Si 2.00 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 26-30, Ni 4-7	C 0.20-0.50, Mn 2.00 max, Si 2.00 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 26-30, Ni 8-11	C 0.20-0.40, Mn 2.00 max, Si 2.00 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 19-23, Ni 9-12
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.279	0.272	0.274	0.277	0.280
Melting Point, F	2750	2725	2700	2650	2550
Ther Cond (212 F), Btu/hr/sq ft/ft/°F	15.2	12.6	12.6	10.0[b]	9.0
Coef of Exp (70–1200 F), per °F	7.5×10^{-6}	6.4×10^{-6}	8.0×10^{-6}	9.9×10^{-6}	10.1×10^{-6}
Spec Ht (70 F), Btu/lb/°F	0.11	0.12	0.12	0.14	0.12
Elec Res (70 F), microhm-cm	70	77	81	85	80
Magnetic Permeability	Ferromagnetic	Ferromagnetic	Ferromagnetic	1.3-2.5	1.0
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	29×10^6	29×10^6	27×10^6	25×10^6	28×10^6
Ten Str, 1000 psi[a]	95[d], 107[b]	70–110, 115[c]	85, —	95, 90[c]	85, 100[c]
Yld Str (0.2% offset), 1000 psi[a]	65[d], 81[b]	65–75, 80[c]	48, —	45, 55[c]	45, 50[c]
Elong (2 in.), %[a]	23[d], 21[b]	2–19, 18[c]	16, —	20, 10[c]	35, 25[c]
Hardness (Brinell)[a]	180[d], 220[b]	190–223, —	190, —	200, 270[c]	165, 190[c]
ELEVATED TEMPERATURE PROPERTIES					
Ten Str, 1000 psi	67 (1000 F), 44 (1100 F)	—	36 (1400 F), 23 (1600 F), 15 (1800 F)	—	57 (1200 F), 35 (1400 F), 22 (1600 F)
Yld Str (0.2% offset), 1000 psi	42 (1000 F), 32 (1100 F)	—	—	—	21 (1400 F)
Elong (2 in.), %	36 (1100 F)	—	14 (1400 F), 18 (1600 F), 40 (1800 F)	—	16 (1200 F), 20 (1400 F), 22 (1600 F)
Creep Str (0.0001%/hr), 1000 psi	16 (1000 F), 7.2 (1100 F), 3.1 (1200 F)	1.3 (1400 F), 0.75 (1600 F), 0.36 (1800 F)	3.5 (1400 F), 1.9 (1600 F), 0.9 (1800 F)	4.0 (1400 F), 2.4 (1600 F), 1.4 (1800 F)	13 (1200 F), 6.0 (1400 F), 3.2 (1600 F)
Rupture Str, 1000 psi					
10 hr	45 (1000 F)	4.6 (1400 F), 2.0 (1600 F), 1.1 (1800 F)	14 (1400 F)	—	37 (1200 F), 20 (1400 F), 10 (1600 F)
100 hr	37 (1000 F)	3.3 (1400 F), 1.7 (1600 F), 0.85 (1800 F)	10 (1400 F), 5 (1600 F), 2.5 (1800 F)	11 (1400 F), 5.3 (1600 F), 2.5 (1800 F)	30 (1200 F), 14 (1400 F), 6.0 (1600 F)
1000 hr	27 (1000 F)	2.3 (1400 F), 1.3 (1600 F), 0.62 (1800 F)	7 (1400 F)	—	17 (1200 F), 8.0 (1400 F), 3.8 (1600 F)
FABRICATING PROPERTIES					
Annealing Temp, F	1625	—	—	—	1900[e]
Machinability	Fair	Good	Good	Good	Good
Weldability	Weldable by all common methods. Preheating, postheating desirable		Weldable by all common methods. Preheating not required		
USES	Fan blades, furnace rollers, Lehr rolls, refinery fittings, trunnions	Grate bars, dampers, kiln parts, rabble blades, salt pots, tuyeres	Brazing furnace parts, cracking equipment, furnace blowers, pouring spouts, salt pots, gas burner parts	Billet skids, burner nozzles, furnace conveyors, tube supports, soot blower elements	Electrode arms, burner tips, annealing boxes, wear plates, gas burner rings, conveyor belts, dampers

[a]As cast and heat treated values given in that order. [b]Normalized at 1825 F, tempered at 1250 F.
[c]Aged 24 hr at 1400 F, furnace cooled. [d]Annealed. [e]Before cyclic temperature service, 6 hr at 1900 F may improve life. [f]At 1500 F.

Cast Heat Resistant Alloys—continued

ACL Type →	HH		HI	HK	HL
COMPOSITION, %	C 0.20-0.50, Cr 24-48, Mn 2.00 max, Ni 11-14, Si 2.00 max, P 0.04 max, S 0.04 max, Mo 0.5 max, N 0.2 max		C 0.20-0.50, Mn 2.00 max, Si 2.00 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 26-30, Ni 14-18	C 0.20-0.60, Mn 2.00 max, Si 2.00 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 24-28, Ni 18-22	C 0.20-0.60, Mn 2.00 max, Si 2.00 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 28-32, Ni 18-22
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.279		0.279	0.280	0.279
Melting Point, F	2500		2550	2550	2600
Ther Cond (212F), Btu/hr/sq ft/ft/°F	8.2		10.9	8.2	8.2
Coef of Exp (70–1800 F), per °F	10.5×10^{-6}		10.5×10^{-6}	10.0×10^{-6}	9.9×10^{-6}
Spec Ht (70 F), Btu/lb/°F	0.12		0.12	0.12	0.12
Elec Res (70 F), microhm-cm	75-85		—	90	94
Magnetic Permeability	1.0-1.9		1.0-1.7	1.02	1.01
MECHANICAL PROPERTIES	Type I[h]	Type II[i]			
Mod of Elast in Tension, psi	27×10^6	27×10^6	27×10^6	29×10^6	29×10^6
Ten Str, 1000 psi[g]	80, 86	85, 92	80, 90	75, 85	82, —
Yld Str, 1000 psi[g]	50, 55	40, 45	45, 65	50, 50	52, —
Elong (2 in.), %[g]	25, 11	15, 8	12 6	17, 10	19, —
Hardness (Brinell)[g]	185, 200	180, 200	180, 200	170, 190	192, —
ELEVATED TEMPERATURE PROPERTIES					
Ten Str, 1000 psi					
1400 F	33	35	38	—	50
1600	18.5	22	26	23	30
1800 F	9.0	11	—	—	19
Yld Str (0.2% offset), 1000 psi					
1400 F	17	18	—	—	—
1600 F	13.5	14	—	—	—
1800 F	6.3	7.0	—	—	—
Elong (2 in.), %					
1400 F	18	12	6	—	—
1600 F	30	16	12	21	—
1800 F	45	30	—	—	—
Creep Str (0.0001% hr), 1000 psi					
1400 F	3.0	7.0	6.6	6.8	7.0
1600 F	1.7	4.0	3.6	4.2	4.3
2001 F	0.3	0.8	0.8	1.0	—
2150 F	—	—	0.15	0.2	—
Rupture Str, 1000 psi					
10 hr 1400 F	—	20	—	23	—
10 hr 1600 F	—	10	—	11	—
10 hr 1800 F	4.7	6.0	—	6.5	—
100 hr 1400 F	14	14	13	14.5	15
100 hr 1600 F	6.4	7.5	7.5	7.8	9.2
100 hr 2000 F	1.5	1.8	1.9	2.5	—
1000 hr 1400 F	6.5	10	8.5	9.0	—
1000 hr 1600 F	3.8	4.7	4.8	5.0	—
1000 hr 2000 F	—	1.2	1.2	—	—
FABRICATING PROPERTIES					
Annealing Temp, F	1900[d]	1900[d]	—	—	—
Machinability	Fair	Fair	Fair	Good	Good
Weldability	Weldable by all common methods; no preheat or postheat required				
USES	Annealing trays, tube supports, carburizing boxes, exhaust manifolds, radiant tubes, retorts, stoker parts		Billet skids, brazing fixtures, furnace rails, lead pots, tube spacers, retorts	Heat treating fixtures, rabble arms, retorts, brazing fixtures, skid rails	Carrier fingers, enameling furnace fixtures, furnace skids, stack dampers

[g]As cast and heat treated (aged 24 hr at 1400 F, furnace cooled) values given in that order. [h]Partially ferritic. [i]Austenitic

continued

Cast Heat Resistant Alloys—concluded

ACI Type →	HN	HT	HU	HW	HX
COMPOSITION, %	C 0.20-0.50, Mn 2.00 max, Si 2.00 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 19-23, Ni 23-27	C 0.35-0.75, Mn 2.00 max, Si 2.50 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 13-17, Ni 33-37	C 0.35-0.75, Mn 2.00 max, Si 2.50 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 17-21, Ni 37-41	C 0.35-0.75, Mn 2.00 max, Si 2.50 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 10-14, Ni 58-62	C 0.35-0.75, Mn 2.00 max, Si 2.50 max, P 0.04 max, S 0.04 max, Mo 0.5 max, Cr 15-19, Ni 64-68
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.283	0.286	0.290	0.294	0.294
Melting Point, F	2500	2450	2450	2350	2350
Ther Cond (212F), Btu/hr/sq ft/ft/°F	—	7.7	—	7.7	—
Coef of Exp (70–1800 F), per °F	—	9.8×10^{-6}	9.6×10^{-6}	8.8×10^{-6}	9.2×10^{-6}
Spec Ht (70 F), Btu/lb/°F	0.11	0.11	0.11	0.11	0.11
Elec Res (70 F), microhm-cm	—	100	105	112	—
Magnetic Permeability	1.10	1.10-2.00	1.10-2.00	16.0	2.0
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	27×10^6	27×10^6	27×10^6	25×10^6	25×10^6
Ten Str, 1000 psi[a]	68, —	70, 75[j]	70, 73[k]	68, 84[l]	65, 73[k]
Yld Str, 1000 psi[a]	38, —	40, 45[j]	40, 43[k]	36, 52[l]	36, 44[k]
Elong (2 in.), %[a]	17, —	10, 5[j]	9, 5[k]	4, 4[l]	9, 9[k]
Hardness (Brinell)[a]	160, —	180, 200[j]	170, 190[k]	185, 205[l]	176, 185[k]
ELEVATED TEMPERATURE PROPERTIES					
Ten Str, 1000 psi					
1400 F	—	35	40	32	—
1600 F	—	18.8	19.6	19	20.5
1800 F	—	11	10.0	10	10.7
Yld Str (0.2% offset), 1000 psi					
1400 F	—	26	—	23	—
1600 F	—	15	—	15	17.5
1800 F	—	8.0	6.2	8.0	6.9
Elong (2 in.), %					
1400 F	—	10	—	—	—
1600 F	—	26	20	—	48
1800 F	—	28	28	40	40
Creep Str (0.0001%/hr), 1000 psi					
1400 F	—	8.0	8.5	6.0	6.4
1600 F	6.3	4.5	5.0	3.0	3.2
2000 F	0.9	0.5	0.6	—	0.6
2150 F	—	0.15	—	—	—
Rupture Str, 1000 psi					
10 hr, 1400 F	—	—	—	16	18
10 hr, 1600 F	—	11	—	8.2	10
10 hr, 2000 F	—	—	—	—	2.5
100 hr, 1400 F	—	18	15	10	13
100 hr, 1600 F	9.5	8.5	8.0	6.0	6.7
100 hr, 2000 F	2.5	2.5	—	—	1.7
1000 hr, 1400 F	—	12.5	—	7.8	—
1000 hr, 1600 F	6.5	7.0	6.0	4.5	4.0
1000 hr, 2000 F	0.9	1.8	—	—	0.9
FABRICATING PROPERTIES					
Annealing Temp, F	—	1900[d]	1900[d]	—	—
Machinability	Good	Good	Good	Good	Good
Weldability	Weldable by all common methods; no preheat or postheat required				
USES	Brazing fixtures, chain, nozzles, furnace parts, radiant tubes, tube supports	Air ducts, carburizing boxes, cyanide pots, glass molds, lead pots	Articulated trays, burner tubes, lead pots, cyanide pots, muffles	Cyanide pots, gas retorts, electric heating elements, hearth plates	Autoclaves, calciner tubes, furnace parts, salt bath electrodes, muffles

[j]Aged 24 hr at 1400 F, air cooled. [k]Aged at 1400 F, furnace cooled [l]Aged 48 hr at 1800 F, furnace cooled.

Nitriding Steels

Nitralloy Type →	135	135, Modified	N	EZ	GR
COMPOSITION, %	C 0.30–0.40, Mn 0.40–0.70, Si 0.20–0.40, Cr 0.90–1.40, Al 0.85–1.20, Mo 0.15–0.25	C 0.38–0.45, Mn 0.40–0.70, Si 0.20–0.40, Cr 1.40–1.80, Al 0.85–1.20, Mo 0.30–0.45	C 0.20–0.27, Mn 0.40–0.70, Si 0.20–0.40, Cr 1.00–1.50, Al 0.85–1.20, Mo 0.20–0.30, Ni 3.25–3.75	C 0.30–0.40, Mn 0.50–1.10, Si 0.20–0.40, Cr 1.00–1.50, Al 0.85–1.20, Mo 0.15–0.25, Se 0.15–0.25	C 1.25–1.50, Mn 0.40–0.60, Si 1.25–1.50, Cr 0.20–0.40, Al 1.00–1.50, Mo 0.20–0.30
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.283	0.283	0.283	0.283	0.283
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	30	30	30	30	30
Coef of Ther Exp (32–932 F), per °F	6.5×10^{-6}	6.5×10^{-6}	6.5×10^{-6}	6.5×10^{-6}	6.5×10^{-6}
Spec Ht, Btu/lb/°F	0.11–0.12	0.11–0.12	0.11–0.12	0.11–0.12	0.11–0.12
Elec Res (68 F), microhm-cm	27–29	27–29	27–29	27–29	27–29
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic	Magnetic
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$	$29–30 \times 10^6$
Ten Str (hard. & temp), 1000 psi	138[a], 121[b]	159[a], 145[b]	132[c], 190[d]	126[a]	108[e]
Yld Str (hard. & temp), 1000 psi	120[a], 103[b]	141[a], 125[b]	114[c], 180[d]	90[a f]	84[e]
Elong (in 2 in., hard. & temp), %	20[a], 23[b]	18[a], 20[b]	22[c], 15[d]	17[a]	17[e]
Red. of Area (hard. & temp), %	58[a], 62[b]	56[a], 64[b]	59[c], 43[d]	44[a]	19[e]
Hardness (Brinell, hard. & temp.)	280[a], 230[b]	320[a], 285[b]	277[c], 415[d]	255[a]	—
	Cases produced by nitriding these steels will have hardnesses in the range Rockwell 15N 94 to 95, excepting case on Nitralloy N which will range from about Rockwell 15N 92 to 93				
Impact Str (Izod, hard. & temp), ft-lb	65[a], 80[b]	—	—	—	—
Endurance Limit, 1000 psi[g]	—	45[g1], 24[g2], 90[g3], 80[g4]	—	—	—
THERMAL TREATMENT					
Annealing Temp, F	1650–1700	1650–1700	1500–1550[h]	1650–1700	—
Quenching Temp, F	1700–1750	1700–1750	1625–1675	1700–1750	1625–1675
Tempering Temp, F	1100–1300	1100–1300	1100–1300	1100–1300	1100–1300
Nitriding Temp, F	930–1050 for periods ranging to 100 hr; 24 to 48-hr treatments are most widely used				
FABRICATING PROPERTIES					
Hot Working Temp Range, F	1950–2200	1950–2200	1950–2200	1950–2200	1950–2200
Weldability	Can be welded by atomic hydrogen process using Nitralloy welding rod; also flash welding				
CORROSION RESISTANCE	Provided the outer skin or white layer is not removed, the nitrided case is resistant to alkalis, crude oil, natural gas combustion products, tap water and unagitated salt water. Case is attacked by mineral acids. Removal of the white layer greatly reduces resistance to attack				
USES	Most uses based on resistance to wear. Cylinder liners and barrels in aircraft engines, bushings, shafts, piston pins, spindles and thread guides, cams and camshafts, rubber and paper mill rolls				

[a]Core properties; oil quenched from 1700 F, tempered at 1200 F.
[b]Core properties; oil quenched from 1700 F, tempered at 1300 F.
[c]Core properties; oil quenched from 1650 F, tempered at 1200 F, before nitriding.
[d]Core properties; oil quenched from 1650 F, tempered at 1200 F, after nitriding
[e]Core properties; oil quenched from 1650 F, tempered 5 hr at 1375 F.
[f]Proportional limit.
[g]Heat treated to 269 Bhn and tested (g1) unnitrided, unnotched; (g2) unnitrided with V notch; (g3) nitrided, unnotched; (g4) nitrided with V notch.
[h]Must be cooled rapidly below 1150 F to avoid precipitation hardening.

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DATA
SECTION

Properties of Materials

Nonferrous Metals

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Aluminum and Its Alloys

Type →	1100	3003	3004
COMPOSITION, %	Al 99.0 min	Mn 1.0–1.5	Mn 1.0–1.5, Mg 0.8–1.3
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.098	0.099	0.098
Melting Temp Range, F	1190–1215	1190–1210	1165–1205
Ther Cond (77 F, annealed), Btu/hr/sq ft/°F/ft	128	111	93.8
Coef of Ther Exp (68 to 212 F), per °F	13.1×10^{-6}	12.9×10^{-6}	12.9×10^{-6}
Specific Heat (212 F), Btu/lb/°F	0.22	0.22	0.22
Electrical Resistivity (68 F), microhm-cm			
Annealed	2.92	3.45	4.10
Hard (H18 or H38)[a]	3.02	4.31	4.10
MECHANICAL PROPERTIES			
Mod of Elasticity in Tension, psi	10×10^6	10×10^6	10×10^6
Tensile Strength (75 F), 1000 psi			
Annealed (O)	13	16	26
Half Hard	18 (H14)	22 (H14)	35 (H34)
Hard	24 (H18)	29 (H18)	41 (H38)
Yield Strength (75 F), 1000 psi			
Annealed (O)	5	6	10
Half Hard	17 (H14)	21 (H14)	29 (H34)
Hard	22 (H18)	27 (H18)	36 (H38)
Elongation (in 2 in., 75 F), %[a]			
Annealed O)	35, 45	30, 40	20, 25
Half Hard	9, 20 (H14)	8, 16 (H14)	9, 12 (H34)
Hard	5, 15 (H18)	4, 10 (H18)	5, 6 (H38)
Hardness (Brinell)[b]			
Annealed (O)	23	28	45
Half Hard	32 (H14)	40 (H14)	63 (H34)
Hard	44 (H18)	55 (H18)	77 (H38)
Endurance Limit, 1000 psi			
Annealed (O)	5	7	14
Half Hard	7 (H14)	9 (H14)	15 (H34)
Hard	9 (H18)	10 (H18)	16 (H38)
Shear Strength, 1000 psi			
Annealed (O)	9	11	16
Half Hard	11 (H14)	14 (H14)	18 (H34)
Hard	13 (H18)	16 (H18)	21 (H38)
FABRICATING PROPERTIES			
Annealing Temp, F	650	775	650
Hot Working Temp Range, F	500-950	500-950	500-950
Machinability	Good	Good	Good
Relative Weldability[c]			
Torch	A	A	B
Inert Arc	A	A	A
Electrical Resistance	A	A	A
CORROSION RESISTANCE	High resistance to rural, industrial and marine atmospheres. Good resistance to most neutral or nearly neutral fresh waters; sea water; many foodstuffs; organic acids and anhydrides; alcohols; aldehydes; esters; ketones; oils gasoline, greases, waxes, and other petroleum derivatives; ammonia and ammonium compounds; nitric acid above 82%; essential oils; amides; nitroparaffins; coal tar derivatives; hydrogen peroxide; and many neutral aqueous inorganic salt solutions		
AVAILABLE FORMS	Sheet, plate, wire, rod, bar		
	Rivets, forgings, impact extrusions	Extruded shapes, tubing, forgings	Sheet, plate
USES	Cooking utensils, heat exchangers, pressure and storage tanks		Hydraulic tubing for commercial vehicles, storage tanks
	Chemical equipment, reflectors	Ductwork, truck panels, architectural applications, builders' hardware	

[a] Values given for 1/16-in. sheet and ½-in. bar, in that order. [b] 500-kg load, 10-mm ball.
[c] Letter A indicates most favorable, B less favorable, etc. Values relative to aluminum alloys only.

Type →	5050	5052	5056
COMPOSITION, %	Mg 1.0–1.8	Mg 2.2–2.8, Cr 0.15–0.35	Mn 0.05–0.20, Mg 4.7–5.6, Cr 0.05–0.20
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.097	0.097	0.095
Melting Temp Range, F	1160–1205	1100–1200	1055–1180
Ther Cond (77 F, annealed), Btu/hr/sq ft/°F/ft	111	79.2	67.4
Coef of Ther Exp, per °F			
68 to 212 F	13.2×10^{-6}	13.2×10^{-6}	13.4×10^{-6}
68 to 572 F	14.2×10^{-6}	14.3×10^{-6}	14.5×10^{-6}
Specific Heat (212 F), Btu/lb/°F	0.22	0.22	0.22
Electrical Resistivity (68 F), microhm-cm			
Annealed	—	4.93	5.94
Hard (H18 or H38)[a]	—	4.93	6.39
MECHANICAL PROPERTIES			
Mod of Elasticity in Tension, psi	10×10^6	10.2×10^6	10.3×10^6
Tensile Strength (75 F), 1000 psi			
Annealed (O)	21	28	42
Half Hard	28 (H34)	38 (H34)	—
Hard	32 (H38)	42 (H38)	60 (H38)
Yield Strength (75 F), 1000 psi			
Annealed (O)	8	13	22
Half Hard	24 (H34)	31 (H34)	—
Hard	29 (H38)	37 (H38)	50 (H38)
Elongation (in 2 in., 75 F), %[a]			
Annealed (O)	24	25, 30	—,35
Half Hard	8 (H34)	10, 14 (H34)	—
Hard	6 (H38)	7, 8 (H38)	—,15 (H38)
Hardness (Brinell)[b]			
Annealed (O)	36	47	65
Half Hard	53 (H34)	68 (H34)	—
Hard	63 (H38)	77 (H38)	105 (H18), 100 (H38)
Endurance Limit, 1000 psi			
Annealed (O)	12	16	20
Half Hard	13 (H34)	18 (H34)	—
Hard	14 (H38)	20 (H38)	22 (H38)
Shear Strength, 1000 psi			
Annealed (O)	15	18	26
Half Hard	18 (H34)	21 (H34)	—
Hard	20 (H38)	24 (H38)	32 (H38)
FABRICATING PROPERTIES			
Annealing Temp, F	650	650	650
Hot Working Temp Range, F	—	500–950	500–950
Machinability	Good	Good	Good
Relative Weldability[c]			
Torch	B	B	C
Inert Arc	A	A	A
Electrical Resistance	A	A	B
CORROSION RESISTANCE	High resistance to rural, industrial and marine atmospheres. Good resistance to most neutral or nearly neutral fresh waters; sea water; many foodstuffs; organic acids and anhydrides; alcohols; aldehydes; esters; ketones; oils, gasoline, greases, waxes, and other petroleum derivatives; ammonia and ammonium compounds; nitric acid above 82%; essential oils; amides; nitroparaffins; coal tar derivatives; hydrogen peroxide; and many neutral aqueous inorganic salt solutions		
AVAILABLE FORMS	Sheet, plate, drawn tube	Sheet, plate, wire, rod, bar, drawn tubing	Rod, wire
USES	Decorative refrigerator parts, coiled tubes, builders' hardware	Bus and truck bodies, aircraft tubing, milk crates, fan blades, kitchen cabinets	Cable sheathing, rivets for magnesium

[a]Values given for 1/16-in. sheet and ½-in. bar, in that order. [b]500-kg load, 10-mm ball.
[c]Letter A indicates most favorable, B less favorable, etc. Values relative to aluminum alloys only.

continued

Aluminum and Its Alloys—continued

Type →	2011	2014[a,b]	2017
COMPOSITION, %	Cu 5.0–6.0, Pb 0.2–0.6, Bi 0.2–0.6	Cu 3.9–5.0, Si 0.5–1.2, Mn 0.4–1.2, Mg 0.2–0.8	Cu 3.5–4.5, Mn 0.4–1.0, Mg 0.2–0.8
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.102	0.101	0.101
Melting Temp Range, F	995–1190	950–1180	955–1185
Ther Cond (77 F, annealed), Btu/hr/sq ft/°F/ft	81.7	111.0	99.4
Coef of Ther Exp, per °F			
68 to 212 F	12.8×10^{-6}	12.5×10^{-6}	12.7×10^{-6}
68 to 572 F	13.9×10^{-6}	13.6×10^{-6}	13.9×10^{-6}
Specific Heat, Btu/lb/°F	0.23	0.22	0.22
Electrical Resistivity (68 F), microhm-cm	4.31 (T3)	3.45 (O), 4.31 (T6)	3.83 (O), 5.75 (T4)
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	10.2×10^6	10.6×10^6	10.5×10^6
Tensile Strength, 1000 psi			
Annealed (O)	—	27	26
Heat Treated	55 (T3), 59 (T8)	62 (T4), 70 (T6)	62 (T4)
Yield Strength (0.2% Offset), 1000 psi			
Annealed (O)	—	14	10
Heat Treated	43 (T3), 45 (T8)	42 (T4), 60 (T6)	40 (T4)
Elongation (in 2 in.), %			
Annealed (O)	—	18	22
Heat Treated	15 (T3), 12 (T8)	20 (T4), 13 (T6)	22 (T4)
Hardness (Brinell)			
Annealed (O)	—	45	45
Heat Treated	95 (T3), 100 (T8)	105 (T4), 135 (T6)	105 (T4)
Endurance Limit, 1000 psi			
Annealed (O)	—	13	13
Heat Treated	18 (T3), 18 (T8)	20 (T4), 18 (T6)	18 (T4)
Shear Strength, 1000 psi			
Annealed (O)	—	18	18
Heat Treated	32 (T3), 35 (T8)	38 (T4), 42 (T6)	38 (T4)
FABRICATING PROPERTIES			
Annealing Temperature, F	775	775	775
Solution Temperature, F	950	940	940
Aging Temperature, F	320	340	—
Machinability[c]	A (T3,T8)	A (T6)	A (T4)
Weldability[c]			
Torch	D	D	D
Inert Arc	D	B	B
Electrical Resistance	D	B	A
CORROSION RESISTANCE	Compared to other aluminum alloys, this group has high resistance to rural atmospheres, fairly good resistance to industrial atmospheres, and poor resistance to marine atmospheres and sea water. More susceptible to corrosive attack than other groups of wrought aluminum alloys. Both degree and nature of the attack are greatly influenced by thermal treatment. Clad sheet alloys generally have high corrosion resistance		
AVAILABLE FORMS	Rod, hexagon bar, wire	Extruded shapes, rolled shapes, forgings, rod, bar	Rod, bar, wire
USES	Screw machine products	Heavy duty forgings, power shovel bails, airplane fittings, structural members	Screw machine products

a2014 available clad with 6053.
bSimilar to 2014 is Hardclad 301. Core: 4.0-5.0 Cu, 0.75-1.2 Si, 0.70-1.0 Mn, 0.25-0.55 Mg. Claddings: 0.50-0.90 Si, 0.25-0.75 Mn. 0.80-1.2 Mg.
cLetter A indicates most favorable, B less favorable, etc. Relative to aluminum alloys only.

Aluminum and Its Alloys—concluded

Type ➡	2018	2218	2024[d]
COMPOSITION, %	Cu 3.5–4.5, Mg 0.45–0.9, Ni 1.7–2.3	Cu 3.5–4.5, Mg 1.2–1.8, Ni 1.7–2.3	Cu 3.8–4.9, Mn 0.3–0.9, Mg 1.2–1.8
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.101	0.102	0.100
Melting Temp Range, F	945–1180	940–1175	935–1180
Ther Cond (77 F, annealed), Btu/hr/sq ft/°F/ft	89.0	97.0	111.0
Coef of Ther Exp, per °F			
68 to 212 F	12.4×10^{-6}	12.4×10^{-6}	12.6×10^{-6}
68 to 572 F	13.4×10^{-6}	13.5×10^{-6}	13.7×10^{-6}
Specific Heat, Btu/lb/°F	0.22	0.22	0.22
Electrical Resistivity (68 F), microhm-cm	—	—	3.45 (O), 5.75 (T4)
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	10.8×10^6	10.8×10^6	10.6×10^6
Tensile Strength, 1000 psi			
Annealed (O)	—	—	27
Heat Treated	61 (T61)	48 (T72)	70 (T3)
Yield Strength (0.2% offset), 1000 psi			
Annealed (O)	—	—	11
Heat Treated	46 (T61)	37 (T72)	50 (T3)
Elongation, %			
Annealed (O)	—	—	20[e]
Heat Treated	12 (T61)[f]	11 (T72)[g]	18 (T3)[e]
Hardness (Brinell)			
Annealed (O)	—	—	47
Heat Treated	120 (T61)	95 (T72)	120 (T3)
Endurance Limit, 1000 psi			
Annealed (O)	—	—	13
Heat Treated	17 (T61)	—	20 (T3)
Shear Strength, 1000 psi			
Annealed (O)	—	—	18
Heat Treated	39 (T61)	30 (T72)	41 (T3)
FABRICATING PROPERTIES			
Annealing Temperature, F	775	775	775
Solution Temperature, F	950	950	920
Aging Temperature, F	340	460	375
Machinability[c]	A	A	A (T3)
Weldability[c]			
Torch	D	—	D
Inert Arc	B	—	B
Electrical Resistance	B	—	B
CORROSION RESISTANCE	Compared to other aluminum alloys, this group has high resistance to rural atmospheres, fairly good resistance to industrial atmospheres, and poor resistance to marine atmospheres and sea water. More susceptible to corrosive attack than other groups of wrought aluminum alloys. Both degree and nature of the attack are greatly influenced by thermal treatment. Clad sheet alloys generally have high corrosion resistance		
AVAILABLE FORMS	Forgings	Forgings	Sheet, plate, rod, bar, tubing, wire, rivets, extruded shapes
USES	Aircraft engine cylinder heads and pistons	Aircraft engine cylinder heads and pistons; jet engine impellers and compressor rings	Screw machine products

[c]Letter A indicates most favorable, B less favorable, etc. Relative to aluminum alloys only.
[d]2024 also available as sheet and plate clad with aluminum of 99.3% min purity.
[e]Elongation in 2 in. [f]Elongation in 1½ in. [g]Elongation in ½ in.

Cobalt and Its Alloys

Material →	Cobalt		AMS 5385C	AMS 5537
COMPOSITION, %	Co 99.9	C 0.06–0.3, Co 98	C 0.20–0.35, Mn 1.0 max, Ni 1.5–3.5, Mo 4.5–6.5, Cr 25–30, Fe 2.0 max, Si 1.0 max, B 0.07 max	C 0.05–0.15, Mn 1.0–2.0, Ni 9–11, Cr 19–21, Fe 3.0 max, W 14–16, Si 1.0 max, Co 46–53
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.322	—	0.299	0.333
Melting Point, F	2723	—	2465	2570
Ther Cond, Btu/hr/sq ft/°F/ft	479	—	101 (392 F)	—
Coef of Ther Exp, per °F	6.8×10^{-6}	—	7.8×10^{-6}	—
Magnetic Properties	Magnetic	Magnetic	Magnetic	Magnetic
Curie Temperature	2039	—	—	—
Thermal Neutron Absorption, barns/atom	34.8	—	—	—
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	30×10^6	—	16.8×10^{6} [a]	35×10^6
Tensile Strength, 1000 psi				
Annealed	37	43–75	—	145–165
Sintered	98.5	—	—	—
Cold Worked	100	—	—	—
As Cast	34.4	61	103	—
Aged 50 hr at 1300 F	—	—	125	—
Yield Strength, 1000 psi				
Annealed	28–41	20–65	—	65–85
Sintered	43.8	—	—	—
As Cast	20–43	33	82	—
Aged 50 Hr at 1300 F	—	—	110	—
Elongation (in 2 in.), %				
Annealed	0–8	13	—	70–55
Sintered (1 in.)	13.5	—	—	—
Cold Worked	2–8	—	—	—
As Cast	0–4	5–30	8	—
Aged 50 Hr at 1300 F	—	—	2	—
Hardness (Brinell)				
Annealed	121–131 [d]	138	—	225
Sintered (VHN)	173	—	—	—
As Cast	124–130	100–131	R_A65	—
Aged 50 Hr at 1300 F	—	—	R_A71	—
Compressive Strength, 1000 psi				
Annealed	117	140	—	—
As Cast	122	175	—	—
Mod of Elast in Shear, psi	11.1×10^6	—	—	—
Impact Strength, ft-lb				
Room Temperature	—	—	2.9 [b]	120 [c]
1500 F	—	—	11 [b]	—
THERMAL TREATMENT				
Annealing Temp, F	—	—	2175–2200	2225
Solution Temp, F	—	—	—	2200
Hardening Temp, F	—	—	1475–1500	—
FABRICATING PROPERTIES				
Hot Working Temp Range, F	930–1100	—	—	—
Machinability	Possible	Possible	Poor	Good
Weldability	—	—	Shield arc	Good
CORROSION RESISTANCE	Excellent	Excellent	Resistant to oxidizing media, flue gases	Highly resistant to scaling and oxidation at elevated temperatures
AVAILABLE FORMS	Rondelles, powders	Rondelles, powders	Precision castings, sand castings, bar, sheet, welding rod	Sheet, plate, bar, tubing, wire

[a] At 1500 F as cast.
[b] Charpy V-notch.
[c] Izod impact strength on notched or unnotched specimen; actually specimen stops pendulum.
[d] Hardness of electrolytic cobalt is 270-310 Bhn.

Columbium, Tantalum, Tungsten and Molybdenum

Metal →	Columbium	Tantalum	Tungsten	Molybdenum
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.31	0.60	0.70	0.37
Melting Point, F	4380	5425	6152	4760
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	—	32	96	84
Coef of Ther Exp (70 F), per °F	4.0×10^{-6}	3.8×10^{-6}	2.2×10^{-6}	3.0×10^{-6}
Specific Heat, Btu/lb/°F	0.065	0.036	0.032	0.061
Elec Res (68 F), microhm-cm	13	12.4	5.5[a]	5.2[a]
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	—	27×10^6	50×10^6	42×10^6
Ten Str, 1000 psi				
Annealed	48–59	50–100	—	85–130[b], 88[c]
Cold Worked	96–130	110–180	70–300	120–175[b]
Yld Str, 1000 psi				
Annealed	—	—	—	—
Cold Worked	—	—	—	—
Elong (in 2 in.), %				
Annealed	30	11–40	—	4–7[b], 42[c]
Cold Worked	1	1–1.5	0–2	1[b]
Hardness (Rockwell)				
Annealed	—	E60	—	B95[b]
Cold Worked	—	E95	C40–C67	C22–27[b]
FABRICATING PROPERTIES				
Workability	Must be cold worked	Must be cold worked	Must be hot worked in all but finest wires	Thin sheet can be cold worked; other material hot worked
Annealing Temp, F	1950 in vacuum	1950 in vacuum	1830 protective atmosphere	Anneal to specified mechanical properties
Machinability	Tools similar to those for steels	High speed steel tools at high cutting speeds	Difficult; abrasive wheel cutting recommended	Similar to SAE 1040 steel heat treated to Rockwell C30
Joining	Resistance weld, preferably under water	Resistance weld, preferably under water. Inert-arc weld with special procedures	Braze with high temperature brazing alloys. Weld by resistance or inert-arc methods	Generally rivet or braze. Thin sheets can be resistance welded
CORROSION RESISTANCE	Less resistant than tantalum but practically unattacked at room temperature by most acids excepting hydrofluoric. Less resistant to alkalis	Resembles glass more closely than other metals. Inert at room temperature to practically all acids but hydrofluoric, fuming sulfuric, and mixture of hydrofluoric and nitric. Less resistant to alkalis	Resists most acids and alkalis up to 212 F. Rapidly attacked by mixture of hydrofluoric and nitric acids at room temperature and by aqua regia at 212 F	Moderately resistant to sulfuric, hydrochloric and hydrofluoric acids and alkalis. Dissolved by dilute nitric acid or mixture of hydrofluoric and nitric acids
AVAILABLE FORMS	Sheet, rod, wire, powder, fabricated shapes	Sheet, rod, wire, tubing, powder, fabricated shapes	Bar, sheet, rod, wire, powder	Bar, sheet, wire, tubing, powder
USES	Electronic tubes, rectifiers for low voltage a.c., alloying in stainless steels	Heat exchangers, coils and heaters, especially for processing chlorine, hydrochloric acid or nitric acid; electronic applications; surgery	Lamp filaments, electronic parts, welding electrodes, alloying in ferrous and nonferrous alloys	Electrodes for glass melting, electronic tube components, heating elements for high temperature electric furnaces, spark gaps, electrical contacts

[a]32 F. [b]From powder. [c]Arc melted.

Coppers and Plain Brasses

Type →	Electrolytic Tough Pitch Copper	Deoxidized Copper	Beryllium Copper	Gilding, 95%	Commercial Bronze, 90%
COMPOSITION, %	Cu 99.90 min, O about 0.04	Cu 99.90 min, P 0.015–0.040	Be 1.90–2.15, Co 0.20–0.35, Cu bal	Cu 94.0–96.0, Zn bal	Cu 89.0–91.0, Zn bal
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.321–0.323	0.323	0.296–0.298	0.320	0.318
Melting Temp Range, F	1949–1981	1981	1600–1800	1920–1950	1870–1910
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	226	196	100–110[a]	135	109
Coef of Ther Exp (68–572 F), per °F	9.8×10^{-6}	9.8×10^{-6}	9.3×10^{-6}	10.0×10^{-6}	10.2×10^{-6}
Spec Ht (68 F), Btu/lb/°F	0.092	0.092	0.10[b]	0.09	0.09
Elec Res (68 F annealed), microhm-cm	1.71	2.03	4.82–5.82[a]	3.1	3.9
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	17×10^6	17×10^6	19×10^6	17×10^6	17×10^6
Ten Str, 1000 psi[c]					
Annealed	32, 35	32	60–80, 60–80[e]	34	37, 40
Hard	50, 55	50	165–185, 165–185[f]	56	54, 74
Yld Str, 1000 psi[c,d]					
Annealed	10	10	25–35, 20–30[e]	10	10
Hard	45	45	130–150, 150–170[f]	50	54
Elong (in 2 in.), %[c]					
Annealed	45, 35	45	35–50, 35–50[e]	45	45, 50
Hard	6, 1.5	8	3–12, 2–5[f]	5	5, 4
Hardness (Rockwell)					
Annealed	F40	F40	B50–65[e]	F46	F53
Hard	B50	B50	C36–41[f]	B64	B70
Shear Str, 1000 psi[c]					
Annealed	22, 24	22	50–60[e]	26	28, 30
Hard	28, 29	28	90–100[f]	37	38, 42
Endurance Limit (10^8 cycles), 1000 psi[c]					
Annealed	11	—	30–35, 12–20[e,g]	—	10
Hard	13	19	35–40, 120–140[f,g]	—	17, 21
FABRICATING PROPERTIES					
Cold Workability	Excellent	Excellent	Good	Excellent	Excellent
Hot Workability	Excellent	Excellent	Excellent	Good	Good
Hot Working Temp, F	1400–1600	1400–1600	1050–1475	1400–1600	1400–1600
Annealing Temp, F	700–1200	700–1200	1400–1475	800–1450	800–1450
Machinability Index[h]	20	20	20	20	20
Joining					
Soft Soldering	Excellent	Excellent	Excellent	Excellent	Excellent
Silver Alloy Brazing	Good	Excellent	Good	Excellent	Excellent
Oxyacetylene Welding	Poor	Fair	Poor	Fair	Good
Carbon Arc Welding	Fair	Good	Excellent	Good	Good
Resistance Welding	Poor	Poor	Excellent	Poor	Poor
CORROSION RESISTANCE	Generally good resistance to industrial, rural and marine atmospheres; also gasolines, fuel oils and lacquers. Generally poor resistance to ammonia, ferric and ammonium compounds, and cyanides. Good resistance to weak acids and bases; some resistance to strong acids and bases				
AVAILABLE FORMS	Flat products, rod, wire, tube, pipe, shapes	Tube, pipe, rod, rolled strip	Flat products, rod, wire, tube, pipe, shapes	Rolled strip	Rolled strip, sheet, wire, tube, plate, rod
USES	Architectural trim; automobile radiators; electrical contacts, conductors and switches; ball floats; rivets; chemical process equipment	Plumbing and gas lines; heat exchanger tubes; air, water, gasoline and oil lines; rotating bands	Instrument and valve springs, plunger guides, bushings, bearings, cams, diaphragms, bellows, electrical contacts, resistance welding electrodes	Coins, bullet jackets, fuse caps, primers, jewelry, base for gold plate or vitreous enamel	Grillwork, cosmetic compacts, marine hardware, primer caps, costume jewelry, vitreous enamel base

[a]Heat treated. [b]86-212 F [c]Where two values or ranges appear, second is for wire.
[d]0.5% extension under load except beryllium copper (0.2% offset). [e]Solution annealed.
[f]Annealed and heat treated 2-3 hr at 600 F. [g]Proportional limit. [h]Based on free-cutting brass = 100.

Coppers and Plain Brasses—concluded

Type ➡	Red Brass, 85%	Low Brass, 80%	Cartridge Brass, 70%	Yellow Brass	Muntz Metal
COMPOSITION, %	Cu 84.0–86.0, Zn bal	Cu 78.5–81.5, Zn bal	Cu 68.5–71.5, Zn bal	Cu 63.0–68.5, Zn bal	Cu 59.0–63.0, Zn bal
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.316	0.313	0.308	0.306	0.303
Melting Temp Range, F	1810–1880	1770–1830	1680–1750	1660–1710	1650–1660
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	92	81	70	67	71
Coef of Ther Exp (68–572 F), per °F	10.4×10^{-6}	10.6×10^{-6}	11.1×10^{-6}	11.3×10^{-6}	11.6×10^{-6}
Spec Ht (68 F), Btu/lb/°F	0.09	0.09	0.09	0.09	0.09
Elec Res (68 F, annealed), microhm-cm	4.7	5.4	6.2	6.4	6.2
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	17×10^6	16×10^6	16×10^6	15×10^6	15×10^6
Ten Str, 1000 psi[c]					
Annealed	39, 41	42, 44	44, 48	46, 50	54
Hard	70, 88	74, 107	76	74, 110	—
Yld Str, 1000 psi[c,d]					
Annealed	10	12	11	14	21
Hard	57	59	63	60	—
Elong (in 2 in.), %[c]					
Annealed	48, 48	52, 55	66, 64	65, 60	45
Hard	5, 6	7, 5	8	8, 8	—
Hardness (Rockwell)					
Annealed	F56	F57	F54	F58	F80
Hard	B77	B82	B82	B80	—
Shear Str, 1000 psi[c]					
Annealed	31, 31	32, 32	32, 34	32. 34	40
Hard	42, 48	43, 53	44	43, 55	—
Endur Limit (10^8 cycles), 1000 psi[c]					
Annealed	10.5	14	10	13.5	—
Hard	21, 29	22, 23	21	19, 20	—
FABRICATING PROPERTIES					
Cold Workability	Excellent	Excellent	Excellent	Excellent	Fair
Hot Workability	Good	Fair	Fair	Poor	Excellent
Hot Working Temp, F	1450–1650	1500–1650	1350–1550	—	1150–1450
Annealing Temp, F	800–1350	800–1300	800–1400	800–1300	800–1100
Machinability Index[j]	30	30	30	30	40
Joining					
Soft Soldering	Excellent	Excellent	Excellent	Excellent	Excellent
Silver Alloy Brazing	Excellent	Good	Good	Good	Good
Oxyacetylene Welding	Good	Good	Good	Good	Good
Resistance Welding	Poor	Poor	Fair	Fair	Fair
CORROSION RESISTANCE	Generally good resistance to industrial, rural and marine atmospheres; also gasolines, fuel oils and lacquers. Generally poor resistance to ammonia, ferric and ammonium compounds, and cyanides				
	Good res. to weak acids and bases; some res. to strong acids and bases. Highly res. to dezincification or stress-corrosion cracking.	Susceptible to dezincification and stress corrosion cracking			
		Good res. to weak bases; some res. to strong bases and weak acids; poor res. to strong acids	Some resistance to weak acids and bases; poor resistance to strong acids and bases. Good resistance to sulfides. Poor resistance to soft and high salinity water		
AVAILABLE FORMS	Rolled strip, sheet, wire, tube, pipe	Wire, rolled strip and flat wire	Rolled strip and bar, flat wire, sheet, rod, wire, tube	Rolled strip and flat wire, drawn flat wire, sheet, plate, rod, wire	Rolled strip and bar, sheet, plate, rod, tube
USES	Weatherstrip, electrical sockets, fasteners, heat exchanger tubes, flexible hose, plumbing, jewelry	Ornamental metal work, battery caps, musical instruments, clock dials, pump lines	Automotive radiator cores and tanks, lamp fixtures, fasteners, springs, ammunition components	Grillwork, reflectors, lamp fixtures, fasteners, stencils, plumbing accessories, springs	Architectural trim, large nuts and bolts, condenser plates, hot forgings, valve stems

[c]Where two values appear, second is for wire. [d]0.5% extension under load. [j]Based on free-cutting brass = 100.

Cast Aluminum Bronzes

BBII Grade ➡	9A	9B	9C	9D
COMPOSITION, %	Cu 87.5, Al 9, Fe 3.5	Cu 89, Al 10, Fe 1	Cu 83 min, Al 10–11.5, Fe 3–5, Ni 2.5 max, Mn 0.5 max	Cu 81, Al 11, Fe 4, Ni 4
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.267	0.270	0.272	0.273
Melting Point Range, F	—	1900	1910–1850	1937
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	—	33	—	22
Coef of Ther Exp, per °F	9.5 x 10^{-6} [a]	9.5 x 10^{-6} [b]	9.0 x 10^{-6} [b]	—
Elec Res (68 F), microhm-cm	13	13.5	12	7.5
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	17 x 10^6	15 x 10^6	18 x 10^6	17 x 10^6
Ten Str, 1000 psi				
Sand Cast	75	67	75	95
Sand Cast & Heat Treated	—	90[c]	105[d]	115[e]
Yld Str (0.5% ext), 1000 psi				
Sand Cast	27	32	35	45
Sand Cast & Heat Treated	—	40[c]	52[d]	70[e]
Elongation (in 2 in.), %				
Sand Cast	35	15	18	7
Sand Cast & Heat Treated	—	15[c]	10[d]	5[e]
Hardness (Brinell)				
Sand Cast	120	140	155	195
Sand Cast & Heat Treated	—	180[c]	230[d]	235[e]
THERMAL TREATMENT				
Normalizing Temp, F	Heat to 1500, furnace cool to 1000, air cool			
Quenching Temp, F	1600–1700	1600–1700	1600–1700	1600–1700
Tempering Temp, F	700–1200	700–1200	700–1200	700–1200
FABRICATING PROPERTIES				
Castability	Because of narrow freezing ranges and high shrinkage, aluminum bronzes are difficult to cast. In addition, they are sensitive to gases. In melting, precautions must be taken to minimize stirring and breaking the oxide skin on the surface of the melt to prevent absorption of gases. In pouring, agitation must be avoided, and castings are generally bottom gated to reduce turbulence. Shrinkage difficulties are overcome by use of large risers (to feed the casting) and chills			
Machinability Index (free-cutting brass = 100)	20–30	20–30	20–30	20–30
Weldability	Can be welded by carbon arc, inert-gas-arc and resistance methods. Can be brazed with silver brazing alloys, but require special fluxes			
CORROSION RESISTANCE	Generally good resistance to atmosphere, water and salt water, and salt solutions. Some resistance to alkaline solutions and nonoxidizing inorganic acids. Poor resistance to ammonia compounds, ferric salts and oxidizing inorganic acids			
USES	Machine parts, pump impellers and castings, gears, rolling mill bearings, segments and washers, bearings, chemical plant equipment, pickling equipment such as chains and hooks, marine propellers, pump casings, fittings			

[a] 70-250 F. [b] 70-500F.
[c] Water quenched from 1625 F, tempered at 1125 F, water quenched.
[d] Water quenched from 1625 F, tempered at 1000 F, water quenched.
[e] Water quenched from 1625 F, tempered at 1150 F, water quenched.

Phosphor Bronzes

Type →	Phosphor Bronze, 5% (Grade A)	Phosphor Bronze, 8% (Grade C)	Phosphor Bronze, 10% (Grade D)	Phosphor Bronze, 1.25% (Grade E)
COMPOSITION, %	Cu 94.0 min, Sn 3.5–5.8, P 0.03–0.35	Cu 90.5 min, Sn 7.0–9.0, P 0.03–0.35	Cu 88.5 min, Sn 9.0–11.0, P 0.03–0.25	Cu 98.5 min, Sn 1.0–1.5, P trace
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.320	0.318	0.317	0.321
Melting Temp Range, F	1750–1920	1620–1880	1550–1830	1900–1970
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	47	36	29	120
Coef of Ther Exp (68–572 F), per °F	9.9×10^{-6}	10.1×10^{-6}	10.2×10^{-6}	9.9×10^{-6}
Spec Ht (68 F), Btu/lb/°F	0.09	0.09	0.09	0.09
Elec Res (68 F, annealed), microhm-cm	9.6	13	16	3.6
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	16×10^6	16×10^6	16×10^6	17×10^6
Ten Str, 1000 psi[a]				
Annealed	47, 50	55, 60	66, 66	40, —
Half Hard	68, 85	76, 105	83, 118	55, —
Hard	81, 110	93, 130	100, 147	65, 76
Spring	100, 140	112, —	122, —	75, —
Extra Spring	107, —	120, —	128, —	—, —
Yld Str, 1000 psi[b]				
Annealed	19	24	28	14
Half Hard	55	55	—	—
Hard	75	72	—	50
Elong (in 2 in.), %				
Annealed	64	70	68	48
Half Hard	28	32	32	16
Hard	10	10	13	8
Spring	4	3	4	4
Extra Spring	3	2	3	—
Hardness (Rockwell)				
Annealed	B26	B50	B55	—
Half Hard	B78	B84	B92	B64
Hard	B87	B93	B97	B75
Spring	B95	B98	B101	B79
Extra Spring	B97	B100	B103	—
FABRICATING PROPERTIES				
Cold Workability	Excellent	Good	Good	Excellent
Hot Workability	Poor	Poor	Poor	Good (1450–1600 F)
Annealing Temp, F	900–1250	900–1250	900–1250	900–1200
Machinability Index[c]	20	20	20	20
Joining				
Soft Soldering	Excellent	Excellent	Excellent	Excellent
Silver Alloy Brazing	Good	Good	Good	Excellent
Oxyacetylene Welding	Good	Good	Good	Good
Resistance Welding	Good	Excellent	Excellent	Fair
Common Processes	Blanking, drawing, forming and bending, heading and upsetting, roll threading and knurling, shearing, stamping	Blanking, drawing, forming and bending, shearing, stamping	Blanking, forming and bending, shearing	Blanking, forming and bending, heading and upsetting, shearing, squeezing and swaging
CORROSION RESISTANCE	Generally good resistance to atmosphere, water and salt water, and salt solutions. Some resistance to alkaline solutions and inorganic acids. Poor resistance to organic acids, cyanides, and ferric and ammonium compounds			
AVAILABLE FORMS	Rolled strip, rolled flat wire, rod, wire, tube	Rolled strip, rod, wire		Rolled strip, wire
USES	Bridge bearing plates, chemical hardware, perforated sheets, textile machinery, welding rods, beater bars, bellows, clutch disks, cotter pins, diaphragms, fuse clips, fasteners, lock washers, sleeve bushings, springs, switch parts, truss wire, wire brushes		Heavy bars and plates for severe compression, good wear and corrosion resistance. Bridge and expansion plates	Electrical contacts, flexible hose, pole-line hardware

[a] Two values are for flat products and wire, respectively. [b] 0.5% extension under load. [c] Based on free-cutting brass = 100.

Nickel Silvers

Type →	65-18	65-12	65-12 Leaded	65-10	55-18
COMPOSITION, %	Cu 65, Ni 18, Zn 17	Cu 65, Ni 12, Zn 23	Cu 65, Ni 12, Zn 21, Pb 2	Cu 65, Ni 10, Zn 25	Cu 55, Ni 18, Zn 27
PHYSICAL PROPERTIES					
Density (68 F), lb/cu in.	0.316	0.314	0.314	0.313	0.314
Melting Temp Range, F	1960–2030	1830–1900	1830–1900	1800–1870	1830–1930
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	19	23	22	26	17
Coef of Ther Exp (68–572 F) 10^{-6} per °F	9.0	9.0	9.0	9.1	9.3
Spec Ht/(68 F), Btu/lb/°F	0.09	0.09	0.09	0.09	0.09
Elec Cond (68 F), % IACS	6	8	7.5	9	5.5
MECHANICAL PROPERTIES					
Mod of Elast in Tension, 10^6 psi	18	18	17	17.5	18
Ten Str, 1000 psi					
Annealed	56–60	52–61	52–55	49–63	60
Half Hard	70–86	73	—	73–85	—
Hard	85–103	85	70–89	86–105	100
Extra Hard	—	93	—	95	108
Yld Str, 1000 psi[a]					
Annealed	25–30	18–28	18–24	18–28	27
Half Hard	60–80	60	—	60	—
Hard	74–90	75	60–79	75	85
Extra Hard	—	79	—	76	90
Elong (in 2 in.), %					
Annealed	56–60	35–48	40	35–50	40
Half Hard	7–20	11	—	7–12	—
Hard	3	4	3–18	4–5	3
Extra Hard	—	2	—	3	2.5
Hardness (Rockwell)					
Annealed	B40–55	B22–55	B27	B22–52	B55
Half Hard	B78–83	B80	—	B80	—
Hard	B87	B89	B80–86	B89	B91
Extra Hard	—	B92	—	B92	B96
Shear Str, 1000 psi					
Annealed	—	41	—	41	—
Half Hard	—	47	—	50	—
Hard	—	52	—	55	—
Extra Hard	—	56	—	59	—
FABRICATING PROPERTIES					
Annealing Temp, F	1100–1500	1100–1500	1100–1500	1100–1500	1100–1500
Hot Workability	Poor	Poor	Poor	Poor	Poor
Cold Workability	Excellent	Excellent	Good	Excellent	Good
Machinability Index[b]	20	20	60	20	30
Joining	Soldering, excellent; silver alloy brazing, good to excellent; carbon arc welding, fair; resistance welding, excellent; oxyacetylene welding, good				
CORROSION RESISTANCE	Attacked rapidly by oxidizing acids. Resistant to sodium and potassium hydroxide but attacked rapidly by ammonium hydroxide and moist ammonia. Good resistance to rural and marine atmospheres and to fresh and salt waters. Subject to stress corrosion				
AVAILABLE FORMS	Sheet; strip; rods, bars, and shapes; wire; spring. Forging, extruding and casting alloys are also available				
USES	Most popular. Hardware, marine and automotive trim, camera parts, lighting fixtures, costume jewelry, screws, springs, slide fasteners	Slide fasteners, nameplates, decorative trim, camera parts	Key blanks, gears, pinions, screw machine parts, watch parts, camera and binocular parts, musical instrument parts	Rivets, screws, slide fasteners, optical parts, hollow ware, nameplates	Excellent for springs. Springs and contacts in telephone equipment, electrical controls. Resistance wire, surgical and dental instruments, diaphragms, hardware

[a]0.5% extension under load. [b]Based on free-cutting brass = 100.

Tin and Aluminum Brasses

Type →	Admiralty	Naval Brass	Leaded Naval Brass	Manganese Bronze (A)	Aluminum Brass
COMPOSITION, %	Cu 70.0–73.0, Sn 0.9–1.2, As, Sb, or P 0.10 max, Zn bal	Cu 59.0–62.0, Sn 0.5–1.0, Zn bal	Cu 59.0–62.0, Pb 1.25–2.25, Sn 0.5–1.0, Zn bal	Cu 57.0–60.0, Fe 0.8–2.0, Sn 0.5–1.5, Mn 0.5 max, Zn bal	Cu 76.0–79.0, Al 1.75–2.5, As, Sb, or P 0.10 max, Zn bal
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.308	0.304	0.305	0.302	0.301
Melting Temp Range, F	1650–1720	1630–1650	1630–1650	1590–1630	1710–1780
Ther Cond (68 F), Btu/hr/sq ft/°F/ft	64	67	67	61	58
Coef of Ther Exp (68–572 F), per °F	11.2×10^{-6}	11.8×10^{-6}	11.8×10^{-6}	11.8×10^{-6}	10.3×10^{-6}
Spec Ht (68 F), Btu/lb/°F	0.09	0.09	0.09	0.09	0.09
Elec Res (68 F, annealed), microhm-cm	6.9	6.6	6.6	7.2	7.5
MECHANICAL PROPERTIES[a]					
Mod of Elast in Tension, psi	16×10^6	15×10^6	15×10^6	15×10^6	16×10^6
Ten Str, 1000 psi					
Annealed[b]	53	57	57	65	60
Quarter Hard	—	69	69	77	—
Half Hard	—	75	75	84	—
Yld Str, 1000 psi[b]					
Annealed	22	25	25	30	27
Quarter Hard	—	46	46	45	—
Half Hard	—	53	53	60	—
Elong (in 2 in.), %					
Annealed	65	47	40	33	55
Quarter Hard	—	27	20	23	—
Half Hard	—	20	15	19	—
Hardness (Rockwell)					
Annealed	F75	B55	B55	B65	F77
Quarter Hard	—	B78	B78	B83	—
Half Hard	—	B82	B82	B90	—
Shear Str, 1000 psi					
Annealed	—	40	36	42	—
Quarter Hard	—	43	39	47	—
Half Hard	—	44	40	48	—
FABRICATING PROPERTIES					
Cold Workability	Excellent	Fair	Poor	Poor	Excellent
Hot Workability	Fair	Excellent	Good	Excellent	Fair
Annealing Temp, F	800–1100	800–1100	800–1100	800–1100	800–1100
Machinability Index[c]	30	30	70	30	30
Joining					
Soft Soldering	Excellent	Excellent	Excellent	Excellent	Good
Silver Alloy Brazing	Good	Good	Good	Good	Good
Oxyacetylene Welding	Good	Good	Fair	Good	Good
Resistance Welding	Fair	Fair	Poor	Good	Good
CORROSION RESISTANCE	Good resistance to industrial, rural and marine atmospheres; petroleum products, alcohols, dry gases and sea water. Fairly good resistance to weak bases. Resistance to some weak bases and weak organic acids, but generally poor resistance to most acids and strong bases. Poor resistance to solutions of cyanides and ammonium compounds. Resistant to dezincification (especially Admiralty and Aluminum Brasses)				
AVAILABLE FORMS	Plate, wire, tube	Rolled strip, rolled and drawn bar, plate, rod, tube, shapes	Drawn bar, rod, shapes	Rod, shapes	Tube
USES	Condenser, evaporator and heat exchanger tubes; condenser tube plates; distiller tubes; ferrules	Aircraft turnbuckle barrels, balls, bolts, marine hardware, nuts, propeller shafts, rivets, valve stems, condenser plates, welding rods	Marine hardware, screw machine products, valve stems	Clutch disks, pump rods, shafting, balls, valve stems and bodies, welding rods	Condenser, evaporator and heat exchanger tubes, distiller tubes, ferrules

[a]Mechanical properties are based on 1-in. dia. Values for Admiralty and Aluminum Brasses apply to tube; other values apply to rod. [b]0.5% extension under load. [c]Based on free-cutting brass = 100.

Lead and Its Alloys (Hard)

Type ➡	1% Sb-Lead	Hard Lead	Hard Lead	8% Sb-Lead	Grid Metal (7-12% Sb)
COMPOSITION, %	Sb 1	Sb 4	Sb 6	Sb 8	Sb 9
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.406	0.398	0.393	0.388	0.385
Melting Temp Range, F	608–595	570–486	545–486	520–486	509–486
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	19	18	17	16	16
Coef of Ther Exp (68–212 F), per °F	16×10^{-6}	15.5×10^{-6}	15.4×10^{-6}	14.5×10^{-6}	14.4×10^{-6}
Spec Ht, Btu/lb/°F	0.031	0.032	0.032	0.032	0.032
Elec Res (68 F), microhm-cm	22	24	25	26.5	27.1
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	2×10^6	—	—	—	—
Ten Str, 1000 psi					
Extruded	2.9	3.1	3.3	3.3	—
Extruded & Aged	3.0	—	—	—	—
Rolled	3.0	4.0	4.1	4.6	4.7
Chill Cast	3.4	5.6	6.8	7.4	7.4
Elong (in 2 in.), %					
Extruded	58	58	65	75	—
Extruded & Aged	50	—	—	—	75
Rolled	60	48	47	31	17
Chill Cast	16	22	24	19	—
Hardness (Brinell)					
Extruded	5.1	8.9	10.7	12.4	—
Extruded & Aged	7	—	—	—	—
Rolled	5.9	8	—	9.5	7.8
Chill Cast	7	10	11.8	13.3	15.4
Endurance Limit, psi[a]					
Extruded	—	—	1200	—	—
Extruded & Aged	1150	—	—	—	—
Rolled	—	1500	1500	1750	—
Chill Cast	—	—	2500	—	2700
Creep Str (86 F)[b]					
Extruded	350	210	—	—	—
Rolled	—	250	400	425	400
FABRICATING PROPERTIES					
Casting Temp Range, F	750–925	750–925	750–850	750–925	750–925
Joining	Soft solder with 50–50 or 40–60 solder using rosin or stearic acid flux. Oxy-hydrogen welding (lead burning): no flux, slightly reducing flame				
CORROSION RESISTANCE	Similar to soft lead (see next page)				
USES	Cable sheathing	Rolled sheet for roofing and flashing; extruded pipe for corrosion resistance applications requiring greater strength than soft lead			Battery grids

[a] 2×10^7 cycles.
[b] 1% extension in 10,000 hr.

Lead and Its Alloys (Soft)

Type ➡	Chemical Lead	Common Lead (soft lead)	Tellurium Lead
COMPOSITION, %	Pb 99.90+	Pb 99.73+	Te 0.05, Cu 0.06 max
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.41	0.41	0.41
Melting Point, F	618	621	617
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	19.6	19.6	19.3
Coef of Ther Exp, per °F	16.3×10^{-6}	16.3×10^{-6}	16×10^{-6}
Specific Ht (32 F), Btu/lb/°F	0.031	0.031	0.031
Electrical Resistivity (68 F), microhm-cm	—	20.6	—
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	2×10^6	2×10^6	1.5×10^6
Tensile Strength, psi			
Rolled	2450	2090	—
Extruded	2200	2000	—
Sand Cast	—	1800	—
Chill Cast	2200	2000	—
Yield Strength, psi			
Rolled	1640	—	—
Extruded	—	—	1500
Sand Cast	—	800	—
Elongation (in 2 in.), %			
Rolled	57	43	40
Extruded	48	—	—
Sand Cast	—	30	—
Chill Cast	40	47	—
Reduction of Area, %			
Sand Cast	—	100	—
Chill Cast	—	100	—
Hardness (Brinell)			
Extruded	—	—	6
Sand Cast	—	3.2–4.5	—
Chill Cast	—	4.2	—
Impact Strength (Charpy, chill cast), ft-lb	—	10	—
Endurance Limit (10^7 cycles), psi			
Extruded & Aged	725	470	1000
Sand Cast	—	470	—
Shear Strength, psi			
Sand Cast	—	1820	—
Chill Cast	—	1820	—
Creep Strength (0.1% per yr, rolled, 85 F), psi	300	250	300
FABRICATING PROPERTIES	Formed by cold rolling and extrusion		
Casting Temp Range, F	790–850	790–850	790–850
Joining	Soft solder with 50-50 or 40-60 solder using rosin or stearic acid flux. Oxyhydrogen welding (lead burning); slightly reducing flame; no flux		
CORROSION RESISTANCE	Resistant to sulfuric, sulfurous, phosphoric and chromic acids. Attacked by acetic, formic and nitric acids. Resistant to atmosphere and fresh and salt water		
AVAILABLE FORMS	Castings, rolled and extruded shapes, sheet		
USES	Chemical apparatus	Storage batteries, cable sheath, ammunition, caulking, alloying, coatings, liquid baths for heat treating	Chemical apparatus

Magnesium Alloys

ASTM Type →	M1A	AZ31B-F	AZ61A-F	AZ80A-F	TA54A
COMPOSITION, %	Mn 1.20 min	Al 2.5–3.5, Zn 0.6–1.4, Mn 0.20 min	Al 5.8–7.2, Zn 0.4–1.5, Mn 0.15 min	Al 7.8–9.2, Zn 0.2–0.8, Mn 0.12 min	Al 3.0–4.0, Sn 4.0–6.0, Mn 0.20 min
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.064	0.064	0.065	0.066	0.067
Melting Temp Range, F	1200	1050–1170	950–1140	900–1115	—
Ther Cond (212–572 F), Btu/hr/sq ft/°F/ft	72.6	55.6	46.0	43.5	—
Coef of Ther Exp, per °F					
65 to 212 F	1.4×10^{-5}	1.4×10^{-5}	1.4×10^{-5}	1.4×10^{-5}	1.4×10^{-5}
65 to 750 F	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}	1.6×10^{-5}
Spec Ht (78 F), Btu/lb/°F	0.25	0.25	0.25	0.25	0.25
Elec Res (68 F), microhm-cm[b]	5.0	10.0	12.5	14.5	13.8
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	6.5×10^6	6.5×10^6	6.5×10^6	6.5×10^6	6.5×10^6
Ten Str, 1000 psi					
Extruded[b]	26–38	35–39	40–45	40–49[a]	—
Forged	36	—	43	46[a]	40
Yld Str, 1000 psi					
Extruded[b]	23–28	23–28	22–32	23–35[a]	—
Forged	23	—	26	31[a]	28
Elong (in 2 in.), %					
Extruded	8–11	12–18	15–16	10–12	—
Forged	7	—	12	8	12
Compr Yld Str, 1000 psi					
Extruded[b]	10–13	15–17	15–21	21–26[a]	—
Forged	—	—	18	25[a]	21
Hardness (Brinell)					
Extruded[b]	42–46	49–50	55–60	60–67	—
Forged	47	—	55	69	52
Shear Str, 1000 psi					
Extruded	16	19	21	21	—
Forged	16	—	21	22	16
Endurance Limit, 1000 psi					
Extruded	9	14	17	19	—
Forged	—	—	16	18	11
Impact Str (Charpy), ft-lb					
Extruded	2.1	3.2	3	2.2	—
Forged	—	—	2.2	1.8	2
THERMAL TREATMENT					
Annealing Temp, F	700	650	650	725	650
Stress Relief Temp, F[d]	500	500	500	400	—
Solution Temp, F	—	—	—	750	—
Aging Temp, F	—	—	—	350	—
FABRICATING PROPERTIES					
Hot Working Temp Range, F[c]	550–650	450–650	450–650	275–375	450–820
Weldability[e]					
Torch	A	B	C	D	B
Inert-Gas-Arc	A	A	A	C	C
Elec Res	A	A	A	A	B
Machinability Index (free-cutting brass = 100)	500	500	500	500	500
Hot Formability[e]	A	A	B	C	B
Cold Formability	B	A	C	D	C
CORROSION RESISTANCE	High resistance to atmosphere				Good atm res.
AVAILABLE FORMS	Sheet, plate, rod, bar, extruded shapes, tubing		Rod, bar, extruded shapes, tubing, forgings		Rod, bar, forgings
APPLICATIONS	Air frame parts, textile machinery, truck bodies, jet engine parts				

[a]Tensile, tensile yield and compressive yield strengths, and hardness of AZ80A-F can be increased several per cent by heat treating, at some expense to elongation.
[b]Generally, strengths and hardness of extruded bar are highest, extruded tubing lowest, and extruded shapes intermediate in the ranges of values given.
[c]Higher working temperatures can be used if they do not require heating hard rolled or aged alloys above the annealing or aging temperature. [d]For extrusions. [e]Letter A indicates most favorable, B less favorable, etc. Relative to magnesium alloys only.

Cast Magnesium Alloys

Type[a] ➡	AZ63A	M1B	AZ92A	AM100A	AZ91A
COMPOSITION, %	Al 5.3–6.7, Zn 2.5–3.5, Mn 0.15 min	Mn 1.20 min	Al 8.3–9.7, Zn 1.6–2.4, Mn 0.10 min	Al 9.3–10.7, Zn 0.3 max, Mn 0.10 min	Al 8.3–9.7, Zn 0.4–1.0, Mn 0.13 min
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.067	0.064	0.066	0.066	0.066
Melting Temp Range, F	850–1135	1200	830–1100	865–1100	875–1105
Ther Cond (212–572 F), Btu/hr/sq ft/°F/ft	43.5	72.6	41.1	40.7	41.1
Coef of Ther Exp (66–212 F), per °F	1.4×10^{-5}	1.4×10^{-5}	1.4×10^{-5}	1.4×10^{-5}	1.4×10^{-5}
Spec Ht (78 F), Btu/lb/°F	0.25	0.25	0.25	0.25	0.25
Elec Res, microhms-cm					
As Cast	11.5	6.6	15.0	15.0	17.0
Solution Treated	14.0	—	17.0	17.5	—
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	6.5×10^6	6.5×10^6	6.5×10^6	6.5×10^6	6.5×10^6
Ten Str, 1000 psi					
As Cast	29	14	24	22	36
Sol'n Treated	40	—	40	40	—
Sol'n Treated & Aged	40	—	40	40	—
Yield Str, 1000 psi					
As Cast	14	4.5	14	12	23
Sol'n Treated	14	—	14	13	—
Sol'n Treated & Aged	19	—	22	19	—
Elongation (in 2 in), %					
As Cast	6	5	2	2	4
Sol'n Treated	12	—	10	10	—
Sol'n Treated & Aged	5	—	2	1	—
Hardness (Brinell)					
As Cast	50	33	65	53	60
Sol'n Treated	55	—	63	52	—
Sol'n Treated & Aged	73	—	83	69	—
Shear Str, 1000 psi					
As Cast	18	11	19	18	20
Sol'n Treated	19	—	20	20	—
Sol'n Treated & Aged	21	—	21	22	—
Endurance Limit, 1000 psi					
As Cast	11	—	11	10	14
Sol'n Treated	14	—	14	11	—
Sol'n Treated & Aged	13	—	13	10	—
Impact Str (Izod), ft-lb					
As Cast	3	9	1	2	2
Sol'n Treated	5	—	4	4	—
Sol'n Treated & Aged	2	—	1	2	—
THERMAL TREATMENT					
Solution Temp, F	730	—	760	790	—
Aging Temp, F	375	—	420	400	—
Stabilizing Temp, F	500	—	500	500	—
FABRICATING PROPERTIES					
Casting Temp, F					
Sand	1350–1550	1350–1550	1350–1550	1350–1550	—
Chill	1200–1500	—	1200–1500	1200–1500	1150–1250
Weldability[b,c]	D, D, A	A, A, A	D, A, A	D, A, A	—
Machinability Index[d]	500	500	500	500	500
CORROSION RESISTANCE					
Resistance to Atmosphere	Good	Good	Good	Good	Good
Resistance to Salt Water[b]	B	A	B	D	B
AVAILABLE FORMS	Sand castings	Sand castings	Sand and perm mold castings	Sand and perm mold castings	Die castings
USES	Parts for aircraft landing wheels and reciprocating and jet type engines. Vacuum cleaners, portable grinders and drills, foundry flasks, textile machinery, pistons. Various fittings				

[a]ASTM B80-55T, B199-55T and B94-54. [b]Letter A indiates most favorable, B less favorable, etc. Relative to magnesium alloys only. [c]Ratings for torch, inert-arc and electrical resistance methods in that order. [d]Based on free-cutting brass = 100.

Nickel and Its Alloys

Type →	A Nickel	Low Carbon Nickel	Duranickel
COMPOSITION, %	Ni 99.45, C 0.06, Mn 0.25, Fe 0.15, S 0.005, Si 0.05, Cu 0.05	Ni 99.55, C 0.01, Mn 0.20, Fe 0.15, S 0.005, Si 0.05, Cu 0.05	Ni 93.90, C 0.15, Mn 0.25, Fe 0.15, S 0.005, Si 0.55, Cu 0.05, Al 4.05, Ti 0.45
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.321	0.321	0.298
Melting Temp Range, F	2615–2635	2615–2635	2550–2620
Ther Cond (80–212F), Btu/hr/sq ft/°F/ft	36	36	10.7 (soft), 11.2 (age hardened)
Coef of Ther Exp (80–212 F), per °F	7.4×10^{-6}	7.4×10^{-6}	7.2×10^{-6}
Specific Heat (80–212 F), Btu/lb/°F	0.130	0.130	0.104
Electrical Resistivity (32 F), microhm-cm	9.5	9.5	46.5 (soft)
Magnetic Transformation Temp, F	680	680	120 (soft)
Magnetic Properties	Magnetic	Magnetic	Slightly magnetic
MECHANICAL PROPERTIES[a]			
Modulus of Elasticity in Tension, psi	30×10^6	30×10^6	30×10^6
Tensile Strength, 1000 psi			
Annealed	55–75	50–60	90–120
Annealed, Age Hardened	—	—	160–190
Spring	90–130	—	155–190
Spring Age Hardened	—	—	180–230
Yield Strength, 1000 psi			
Annealed	15–30	12–25	35–60
Annealed, Age Hardened	—	—	—
Spring	70–115	—	—
Spring, Age Hardened	—	—	—
Elongation (in 2 in.) %			
Annealed	55–40	60–40	50–130
Annealed, Age Hardened	—	—	25–10
Spring	15–2	—	10–2
Spring, Age Hardened	—	—	15–5
Hardness (Rockwell)			
Annealed	B64 (max)	B55 (max)	B90 (max)
Annealed, Age Hardened	—	—	C30–40
Spring	B95 (min)	—	C30–40
Spring, Age Hardened	—	—	C36–46
Endurance Limit (10^8 cycles), 1000 psi			
Hot Rolled	33	33	51
Hot Rolled, Age Hardened	—	—	52.5
Cold Drawn	50	50	51
Cold Drawn, Age Hardened	—	—	61
THERMAL TREATMENTS			
Annealing Temperature, F	1500 (2–5 min)	1500 (3–6 min)	1600 (2–5 min)
Aging Temperature, F	—	—	1100 (8–16 hr)
FABRICATING PROPERTIES			
Hot Working Temp Range, F			
Heavy Forging, Drop Forging	1600–2300	1400–2300	1900–2300
Light Forging	1200–1600	1200–1600	1600–1900
Joining	Metallic arc, inert-gas metal arc, oxyacetylene and resistance welding; silver and copper brazing; soft soldering		Metallic arc, inert-gas metal arc and resistance welding; silver brazing; soft soldering
AVAILABLE FORMS	Sheet, strip; rods, bars and shapes; tube; plate		
USES	Generally used in process equipment for resistance to corrosion and high temperatures. Also used in electronic equipment for vacuum tube parts, leads and springs	Equipment for production and handling of molten caustic soda and other molten salts. Spun or coined parts. Long time service at 700–1200 F	Parts requiring corrosion resistance and strength at elevated temperatures, such as springs, dies for extruding plastics, fasteners, vacuum tube components

[a]Values are for sheet and strip unless otherwise specified.

Nickel and Its Alloys—concluded

Name →	Monel	K Monel	Inconel	Inconel X
NOMINAL COMPOSITION, %	Ni 66.00, C 0.12, Mn 0.90, Fe 1.35, S 0.005, Si 0.15, Cu 31.50	Ni 65.30, C 0.15, Mn 0.60, Fe 1.00, S 0.005, Si 0.15, Cu 29.50, Al 2.80, Ti 0.50	Ni 76.40, C 0.04, Mn 0.20, Fe 7.20, S 0.007, Si 0.20, Cu 0.10, Cr 15.85	Ni 72.80, C 0.04, Mn 0.70, Fe 6.75, S 0.007, Si 0.30, Cu 0.05, Cr 15.15, Al 0.80, Ti 2.55, Cb+Ta 0.85
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.319	0.306	0.304	0.298
Melting Temp Range, F	2370–2460	2400–2460	2540–2600	2540–2600
Ther Cond (80–212 F), Btu/hr/sq ft/°F/ft	15	10.8	8.7	8.7
Coef of Ther Exp (77–212 F), per °F	7.8×10^{-6}	7.8×10^{-6}	6.4×10^{-6}	9×10^{-6}
Spec Heat (70–750 F), Btu/lb/°F	0.127	0.127	0.109	0.10–0.11
Elec Res (68 F), microhm-cm	48.2	58.3	98.1	124.6 (122 F)
Magnetic Properties	Slightly magnetic	Nonmagnetic to −150 F	Nonmagnetic	Nonmagnetic
MECHANICAL PROPERTIES[a]				
Mod of Elast in Tension, psi	26×10^6	26×10^6	31×10^6	31×10^6
Ten Str, 1000 psi				
Annealed	70–85	90–105	80–100	110–130
Annealed, Age Hardened	—	130–170	—	155–180
Spring	100–140	145–165	145–170	200–225
Spring, Age Hardened	—	170–200	—	250–285
Yld Str, (0.2% offset), 1000 psi				
Annealed	25–45	40–65	30–45	45–65
Annealed, Age Hardened	—	90–120	—	100–125
Spring	90–130	130–160	120–160	230–240
Spring, Age Hardened	—	130–180	—	260–290
Elong (in 2 in.), %				
Annealed	50–35	45–25	55–35	40–55
Annealed, Age Hardened	—	25–15	—	30–20
Spring	15–2	8–3	10–2	1.6 (approx)
Spring, Age Hardened	—	10–5	—	1
Hardness (Rockwell)				
Annealed	B68 (max)	B85 (max)	B84 (max)	B95 (max)
Annealed, Age Hardened	—	C24–33	—	C30–37
Spring	B98 (min)	C25–32	C30 (min)	—
Spring, Age Hardened	—	C34–40	—	—
THERMAL TREATMENTS				
Annealing Temp, F	1600–1800 (open), 1400–1500 (box)	1400–1800 (1–5 min)	1600–1800	1900–2000 (15–30 min)
Solution Temp, F	—	—	—	2100 (2–4 hr, a.c.[c])
Aging Temp, F	—	1100 (8–16 hr, f.c.[c])	—	1550 (24 hr, a.c.), 1300 (20 hr, a.c.[c])
FABRICATING PROPERTIES				
Hot Working Temp Range (hot forging, drop forging), F	1700–2150	1900–2150	1700–2300	1800–2200
Cutting Speed, fpm[b]	125–225	100–200	100–175	—
Joining Methods	Metal arc, inert-gas metal arc, oxyacetylene and resistance welding; silver and copper brazing; soft soldering		Metal arc, inert-gas metal arc and resistance welding; silver brazing	
AVAILABLE FORMS	Sheet, strip, rod, bar, shapes, tube, plate			Sheet rod, bar, shapes
USES	Applications requiring combination of good strength, ductility and corrosion resistance. Condenser and heat exchanger tubes; pickling baskets, hooks and rods; pump shafts; valve stems; springs; fasteners	Applications requiring greater strength and hardness than monel with same corrosion resistance and strength comparable with that of mild steel. Pump shafts and liners, valve seats and stems, electrical contact arms	Food processing equipment, such as cookers, kettles, steamers and storage tanks. Other process equipment requiring similar combination of strength, corrosion resistance and good elevated temperature properties	High strength, high temperature alloy (can operate extended periods at 1000 F) for application in steam turbines, jet engines, heat treating equipment. Furnace muffles, springs, turbine blades, bellows, fasteners

[a]Values are for sheet and strip unless otherwise specified. [b]Surface speed with single point cemented carbide tools.
[c]a.c.—air cool, f.c.—furnace cool.

Cast Nickel Alloys

Type →	Nickel	Inconel	S Inconel	Monel	S Monel
COMPOSITION, %	Ni 95.6, Cu 0.5, Fe 0.5, Si 1.5, Mn 0.8, C 0.80, S 0.008	Ni 71.5, Cu 0.50, Fe 8.0, Cr 16.0, Si 2.0, Mn 1.0, C 0.20, S 0.008	Ni 68.0, Cu 0.5, Fe 8.5, Mn 1.0, Si 5.5, Cr 15.5, S 0.008, C 0.20	Ni 63.0, Cu 32.0, Fe 1.5, Si 1.6, Mn 0.75, C 0.15, S 0.015	Ni 63.0, Cu 30.0, Fe 2.0, Si 4.0, Mn 0.75, C 0.1, S 0.015
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.301	0.300	0.292	0.312	0.302
Melting Temp Range, F	2450–2600	2500–2550	—	2400–2450	2300–2350
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	34.2	8.7	—	15.5	11.3
Coef of Ther Exp (70–1400 F), per °F	8.85×10^{-6}	8.92×10^{-6}	9.20×10^{-6}	9.0×10^{-6}	8.7×10^{-6}
Spec Ht (80–750 F), Btu/lb/°F	0.13	0.11	—	0.13	0.13
Elec Res (32 F), microhm-cm	20.8	11.6	12.6	53.2	63.1
Magnetic Trans Temp, F	680	–40	—	110–140	–70
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	21.5×10^6	23×10^6	25×10^6	23.0×10^6	24.2×10^6
Mod of Elast in Torsion, psi	11.0×10^6	11.0×10^6	—	9.5×10^6	9.5×10^6
Ten Str, 1000 psi					
Annealed & Aged	—	—	75–30	—	120–145
As Cast	50–65	65–90	90–120	65–90	120–145
Yld Str (0.5% ext), 1000 psi					
Annealed & Aged	—	—	55–70	—	85–130
As Cast	15–30	—	80–100	32–45	80–130
Elong (in 2 in.), %					
Annealed & Aged	—	—	4–1	—	1–4
As Cast	30–15	20–10	3–1	20–50	1–4
Hardness (Brinell)					
Annealed & Aged	—	—	300–380	—	300–380
As Cast	90–130	150–300	300–380	125–150	275–350
Impact Str (Charpy, rm temp), ft-lb	90–75	24	—	80–65	9–3
FABRICATING PROPERTIES					
Pouring Temp, F	2700–2900	2800–2950	2700–2900	2700–2850	2650–2800
Pattern Shrinkage, in./ft	0.25	0.25	0.25	0.25	0.25
Weldability	Fabrication or repair by any standard process[a]	Repair welding by any standard process[a]	Not recommended	Limited amount of repair welding[a]	Not recommended
CORROSION RESISTANCE	Good corrosion resistance, especially to hot concentrated caustic soda, and chlorine and fluorine gases	Resistance to nitric acid, ammonium hydroxide and oxidizing conditions superior to that of nickel. Good resistance to oxidation at temperatures up to 2200 F. Good resistance to corrosive vapors above 800 F		Good resistance to flowing salt water; dilute acids; hydrochloric, hydrofluoric, sulfuric, phosphoric and most organic acids; and strong caustic soda. Not resistant to strongly oxidizing solutions such as nitric acid and ferric chloride	
USES	Evaporators, tanks, heating coils, tubular condensers and other processing equipment; magnetostrictive devices; applications in incandescent lamp and radio industries	Dairy equipment, food handling equipment, airplane exhaust manifolds, utensils. Used extensively in oxidizing and carburizing atmospheres at elevated temperatures. Inconel S castings have higher resistance to wear and galling than Inconel		Valve seats, liners, pump rods, bushings, nozzles, turbine blading, pickling equipment, laundry machines, paper mill and oil refinery equipment, food-handling equipment, storage tanks, boilers. Monel S castings have higher resistance to galling and erosion than Monel	

[a]For joining by welding, a weldable grade is available.

Low Expansion Nickel Alloys

Composition (%)[a] →	Ni 36	Ni 42	Ni 47-50
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.292	0.292	0.296
Melting Point, F	2600	2606	2600
Ther Cond (68–212 F), Btu/hr/sq ft/°F/ft	6.05	6.21	6.91
Coef of Ther Exp, per °F			
−200 to 0 F	1.10×10^{-6}	3.42×10^{-6}	5.37×10^{-6}
0 to 200 F	0.70×10^{-6}	3.18×10^{-6}	5.55×10^{-6}
200 to 400 F	1.50×10^{-6}	2.97×10^{-6}	5.55×10^{-6}
400 to 600 F	6.35×10^{-6}	3.15×10^{-6}	5.55×10^{-6}
600 to 800 F	8.61×10^{-6}	5.50×10^{-6}	5.60×10^{-6}
800 to 1000 F	9.48×10^{-6}	8.55×10^{-6}	7.26×10^{-6}
Specific Heat (77–212 F), Btu/lb/°F	0.123	0.121	0.120
Electrical Resistivity (68 F), microhm-cm	81	70	48
Poisson's Ratio	0.290	0.290	0.290
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	21×10^6	22×10^6	24×10^6
Tensile Strength, 1000 psi			
Annealed	70	76	82
Cold Worked	90	120	140
Yield Point, 1000 psi			
Annealed	24	28	31
Cold Worked	70	—	—
Elongation (in 2 in.), %			
Annealed	36	38	41
Cold Worked	20	—	—
Reduction of Area, %			
Annealed	68	70	72
Cold Worked	60	—	—
Hardness			
Annealed (Brinell)	143	156	170
Cold Worked (Rockwell)	—	B100	B103
Modulus of Rigidity, psi	8.1×10^6	8.5×10^6	9.3×10^6
FABRICATING PROPERTIES			
Annealing Temp, F	Soften progressively in range 1000 to 2300 F		
Hot Working Temp Range, F	To 2300 F	To 2300 F	To 2300 F
Machinability	Machine best at a hardness of about Rockwell C20		
Weldability	Can be welded by acetylene torch, metal arc, carbon arc and resistance methods		
CORROSION RESISTANCE	Resistant to atmospheric corrosion and to fresh and salt water		
AVAILABLE FORMS	Bars, plate, sheet, strip, wire, tubing, forgings, castings		
USES	Length standards, instruments, hypodermic syringes, textile machine parts, thermostatic bimetal — up to 400 F	Higher temperature thermostatic bimetal, instruments, glass sealing — up to 650 F	Higher temperature low expansion applications—up to 1000 F

[a]Balance iron.

Precious Metals

Metal →	Gold[a]	Silver[b]	Platinum[c]	Palladium[b]
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.698	0.379	0.775	0.434
Melting Point F	1945	1761	3224	2829
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	172	242	42	41
Coef of Ther Exp (32–212 F), per °F	7.9×10^{-6}	10.9×10^{-6}	4.9×10^{-6}	6.5×10^{-6}[a]
Specific Heat, Btu/lb/°F	0.031	0.056	0.031	0.058
Elec Res (32 F), microhm-cm	2.35	1.59[d]	14.9	10.8[a]
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	12×10^6	11×10^6	21×10^6	17×10^6
Ten Str, 1000 psi				
Annealed	19	22	17–26	30
Cold Worked	32[e]	54[f]	34–45	47
As Cast	18	15	—	—
Yld Str, 1000 psi				
Annealed	Nil	8	2–5.5	5
Cold Worked	30	44	27	30
As Cast	—	5	—	—
Elong (in 2 in.), %				
Annealed	45	48	30–40	24–40
Cold Worked	4	2.5	2.5–3.5	1.5
As Cast	30	60	—	—
Red. of Area (as cast), %	—	67	—	—
Hardness (Brinell)				
Annealed	25	25–35	38–52	46
Cold Worked	58	—	97–13	109
As Cast	33	42	—	—
Endurance Limit, 10 cycles, annealed, 1000 psi	4.6	—	—	—
FABRICATING PROPERTIES				
Annealing Temp, F	—	400–600	1475–2200	1475
Hot Working Temp Range, F	Any to melting point	—	1475–2300	1475–2300
Max Red. Between Anneals, %	Apparently unlimited	—	99	99
Casting Temp Range, F	2000–2370	2000	3300	3000
Joining	Braze with silver solder, no flux, any flame. Can be resistance welded by any method. Oxyacetylene weld with no flux, any flame	Braze with silver solder. Can be resistance welded	Braze with fine gold or white platinum solder. Hammer weld at 1800 F. Can be resistance or oxyacetylene welded	Braze with oxyacetylene torch using platinum solders. Can be resistance welded
CORROSION RESISTANCE	Does not oxidize when heated in air. Resists alkalis, salts and most acids. Not attacked by oxygen or sulfur. Rapidly attacked by chlorine and bromine	Does not oxidize when heated in air. Resists most dilute mineral acids and alkalis. Attacked rapidly by nitric and hot sulfuric acids. Attacked rapidly by sulfur-bearing gases	Does not oxidize when heated in air. Resists reducing or oxidizing acids alone but is dissolved by aqua regia	Oxidizes when heated in air. Resists hydrofluoric, acetic and phosphoric acids. Attacked by nitric, sulfuric and hydrochloric acids; and bromine and iodine
AVAILABLE FORMS	Foil, rod, wire, sheet	Sheet, strip, rod, wire, tubing	Foil, sheet, wire, tubing	Sheet, foil, wire, tubing
USES	Lining of chemical equipment, high melting solder, alloys for electrical and chemical purposes, jewelry, dentistry	Electrical contacts, corrosion resisting equipment, bearings, photography supplies; alloying for coinage, brazing alloys, jewelry	Chemical equipment, electrical contacts, catalysts, laboratory equipment, jewelry	Electrical contacts, catalysts, production of pure hydrogen, jewelry, dental alloys

[a]Gold is generally produced in three grades: proof gold, 99.99% Au; refined gold, 99.95-99.98% Au; and 99.5% Au, which is accepted by the U.S. Mint without penalty.
[b]Usually refined to "the high purity suitable for general use"; in some cases spectographically pure.
[c]Platinum is produced in four grades: type A, 99.99% Pt, sometimes called physically pure; type B, 99.9% Pt, sometimes called chemically pure; type C, 99.5% Pt (crucible grade); and type D, 99% Pt (commercial platinum).
[d]68° F. [e]Cold rolled, 60% reduction. [f]Cold rolled, 50% reduction.

Precious Metals—concluded

Metal →	Rhodium[b]	Ruthenium[b]	Osmium[b]	Iridium[b]
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.447	0.441	0.82	0.813
Melting Point, F	3571	4530	4890	4450
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	50	—	—	34
Coef of Ther Exp (68 F), per °F	4.6×10^{-6}	5.1×10^{-6}	3.6×10^{-6}	3.8×10^{-6}
Specific Heat, Btu/lb/°F	0.059	0.057	0.031	0.031
Elec Res (68 F), microhm-cm	4.51	7.6[g]	9.5	5.3
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	42×10^6	60×10^6	80×10^6	74×10^6
Ten Str, 1000 psi				
Annealed	73	—	—	—
Cold Worked	300	—	—	—
Hardness (Brinell)				
Annealed	55–156	—	—	170
Cold Worked	260–390	—	—	350
As Cast	—	220	350	163
FABRICATING PROPERTIES				
Hot Working Temp Range, F	1900–2000	2700–4300	Not workable	2200–2700
Max Red, Between Anneals, %	30–40	—	—	—
Casting Temp, F	3700	4700	5000	4600
Joining	Can be brazed and resistance welded	Can be brazed and resistance welded	Can be brazed and resistance welded	Can be brazed and resistance welded
CORROSION RESISTANCE	Oxidizes slowly when heated in air. Resistant to most acids, including aqua regia at room temperature	Oxidizes when heated in air. Unattacked by common acids, including aqua regia up to 212 F. Moderately attacked by solutions of alkaline hypochlorites	Oxidizes rapidly in air at elevated temperatures. Resists common acids at room temperatures, but is attacked by aqua regia	Oxidizes slowly when heated in air. Unattacked by common acids, including aqua regia up to 212 F
AVAILABLE FORMS	Powder	Powder	Cast or sintered parts	Sheet, wire, rod
USES	Mirrors and electrodeposits for a nontarnishing finish; alloys with platinum and palladium for crucibles, glassworking equipment, catalysts spinnerets	Hardener for platinum and palladium	Alloys used for pen tips, phonograph needles, electrical contacts, instrument pivots	Extrusion dies for glass, alloys with platinum for electrical contacts, fuse wires, hypodermic needles, jewelry

[b]Usually refined to "the high purity suitable for general use"; in some cases spectrographically pure.
[g]At 32 F.

Tin and Its Alloys

Type →	Grade A Tin	Hard Tin	Tin Foil	White Metal	Pewter
COMPOSITION, %	Sn 99.8 min	Sn 99.6, Cu 0.4	Sn 92, Zn 8	Sn 92, Sb 8	Sn 91, Sb 7, Cu 2
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.264	—	—	0.262	0.263
Melting Temp Range, F	449.4	446–441	390	475	563–471
Ther Cond (77 F), Btu/hr/sq ft/°F/ft	37	—	34	—	—
Coef of Ther Exp (32–212 F), per °F	13 x 10^{-6}	—	—	—	—
Spec Ht, Btu/lb/°F	0.054	—	—	—	—
Elec Res (68 F), microhm-cm	11.5	—	12	15	—
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	6–6.5 x 10^6	—	—	—	7.7 x 10^6
Ten Str, 1000 psi					
Annealed Sheet	2.2	3.3	—	6.7	8.6
Cold Rolled Sheet	2.8	4.0	8.7	7.4[b]	7.6
As Cast	2.1	—	—	7.2[c]	—
Yld Str, 1000 psi					
Annealed Sheet	1.3	—	—	—	—
Cold Rolled Sheet	2.0	—	6.0	—	—
As Cast	1.7	—	—	—	—
Elong (in 2 in.), %					
Annealed Sheet	45	—	—	70	40
Cold Rolled Sheet	35	—	40	28[b]	50
As Cast	55[a]	—	—	—	—
Hardness (Bhn)					
Annealed Sheet	7	—	—	17	13[d, f]
Cold Rolled Sheet	8	—	—	—	18[e, f]
As Cast	5–6	—	—	20[c]	23[d, f]
Impact Str (Izod, as cast), ft-lb	14	—	—	22[c]	—
Endurance Limit (as cast), 1000 psi	0.34	—	—	—	—
FABRICATING PROPERTIES					
Casting Temp Range (chill), F	525–550	525–550	—	575–600	600–625
Joining	Bonds easily by simple melting. Eutectic tin-lead solder or low melting fusible alloys might be used on massive parts such as block tin pipe		—	Readily soldered	Can be soldered with some of the fusible alloys
CORROSION RESISTANCE	Resists distilled, sea and soft tap water. Attacked by strong acids, alkalis and acid salts. Oxygen in solution accelerates rate of attack		—	—	Tarnishes in soft water; suffers localized attack at water line in hard water. Attacked by dilute hydrochloric and citric acids in presence of air
AVAILABLE FORMS	Sheet, pipe, foil, castings, powder	Tubing, foil	Foil	Castings, sheet	Castings, sheet
USES	Linings for food cans; pipe for handling water, beer, and carbonated beverages; linings for food processing equipment, food wrappings	Collapsible tubes, foil	Foil for wrapping food, medicines, electrical condensers	Rubber mold castings, cast and wrought costume jewelry	Mountings and ornamental objects such as tea and coffee services, vases and book ends

[a] In 4 in.
[b] Sheet quenched from 425 F.
[c] Chill cast.
[d] Vickers pyramid hardness.
[e] Vickers pyramid hardness after heat treating 3 hr at 300 F.
[f] Hardenable pewter values are: 13, 28, 29, respectively.

Lead-Tin-Antimony Alloys

Grade[a] ➡	1[b]	2	3	4	5[c]
COMPOSITION, %	Sn 91, Sb 4.5, Cu 4.5	Sn 89, Sb 7.5, Cu 3.5	Sn 84, Sb 8, Cu 8	Sn 75, Pb 10, Sb 12, Cu 3	Sn 65, Pb 18, Sb 15, Cu 2
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.265	0.267	0.269	0.272	0.280
Melting Temp Range, F	433–700	466–669	464–792	363–583	358–565
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	7.3×10^6	7.6×10^6	—	—	—
Tens Str, 1000 psi					
Chill Cast	9.3	11	10–12	—	—
Die Cast	10.3	—	—	—	11.8
Elong (in 2 in., die cast), %	22	—	—	—	4
Hardness (Brinell)					
Chill Cast	17	24	27	25	22
Die Cast	—	—	—	—	27.7
Impact Str (Izod, chill cast), ft-lb	2.5	—	1	—	—
End. Limit (chill cast), 1000 psi	3.8[d]	4.8[d]	—	—	—
Compr Str (chill cast), 25% set, 1000 psi	13	15	18	16	15
Compr Yld Str (chill cast, 0.125% set), 1000 psi	4.4	6.1	6.6	5.5	5.0
FABRICATING PROPERTIES					
Casting Temp Range (chill), F	750–825	795	850–915	710	690–700
CORROSION RESISTANCE	Resists oxidation products of lubricants; food products, beer and carbonated beverages	Resist oxidation products of lubricants			
AVAILABLE FORMS	Precision inserts of babbitt-lined strip, lined bearing shells, ingots, die castings			Ingots	Ingots, die castings
USES	Bearings, die castings for dairy machinery, dental appliances, surgical instruments, soda fountain equipment	Most widely used tin-base bearing alloy in automotive field	High load applications, hardest of standard tin babbitts and has greatest load carrying capacity	Limited bearing applications	Limited bearing applications. Die cast parts

[a] ASTM B23-49.
[b] Also die casting Alloy 1, ASTM B102-48.
[c] Also die casting Alloy 3, ASTM B102-48.
[d] 2×10^7 cycles.

continued

Lead-Tin-Antimony Alloys—continued

Grade[a] →	6	7	8	10	11
COMPOSITION, %	Sn 20, Sb 15, Pb 63.5, Cu 1.5	Sn 10, Sb 15, Pb 75	Sn 5, Sb 15, Pb 80	Sn 2, Sb 15, Pb 83	Sb 15, Pb 85
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.336	0.350	0.361	0.362	0.370
Melting Temp Range, F	531–358	514–464	522–459	507–468	504–471
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	—	14	14	—	—
Coef of Ther Exp (68–212 F), per °F	—	10.9×10^{-6}	13×10^{-6}	—	—
Spec Ht, Btu/lb/°F	—	0.065	0.065	—	—
Elec Res (68 F), microhm-cm	—	28.6	28.2	—	—
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	—	4.2×10^6	4.2×10^6	—	—
Ten Str, 1000 psi[e]	—	10.5	10	—	6.8
Elong (in 2 in.), %[e]	—	4	5	—	8
Hardness (Brinell)[e]	21	22	20	18	15
Endurance Limit, 1000 psi[e]	—	4[d]	3.9[d]	—	—
Compr Str (25% deformation), 1000 psi[e]	14.5	15.6	15.6	15.4	12.8
Compr Yld Str (0.125% set), 1000 psi[e]	3.8	3.6	3.4	3.4	3.0
FABRICATING PROPERTIES					
Casting Temp, F (chill)	655	640	645	630	630
CORROSION RESISTANCE	Resistant to corrosion by the usual lubricants				
AVAILABLE FORMS	Small ingots and bars				
USES[f]	General purpose bearing applications	General purpose bearings under moderate loads	Bearings for light loads and moderate speeds. Mining machinery, transmission machinery, car journals	Bearings for light loads and speeds. Blowers, pumps, electric motors, machine tools	Bearings for light loads

[a] ASTM B 23-49.
[d] 2×10^7 cycles.
[e] Chill cast.
[f] Light loads—under 1000 psi; moderate loads—1000 to 2000 psi; heavy loads—over 3000 psi. Surface speeds: low—to 10 fps; moderate—to 20 fps; high—above 80 fps.

Lead-Tin-Antimony Alloys—concluded

Grade[a] ➡	12	15	16	19
COMPOSITION, %	Sb 10, Pb 90	Sn 1, Sb 15, Cu 0.5, As 1.0, Pb bal	Sn 10, Sb 12.5, Cu 0.5, Pb bal	Sn 5, Sb 9, Pb bal
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.384	0.362	0.355	0.378
Melting Temp Range, F	498–473	538–479	495–471	495–462
Coef of Ther Exp (68–212 F), per °F	14.6×10^{-6}	—	—	—
Specific Heat, Btu/lb/°F	0.065	—	—	0.065
Elec Res (68 F), microhm-cm	25.6	—	—	28.7
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	—	4.2×10^6	—	4.2×10^6
Tensile Strength, 1000 psi[e]	—	10.4	—	10
Elongation (in 2 in), %[e]	—	2	—	5
Hardness (Brinell)[e]	14	21	28	18
Endurance Limit, 1000 psi[e]	—	4.3[d]	—	3.7[f]
Compressive Strength, 1000 psi[e] (25% deformation)	12.9	—	—	15.6
Compressive Yield Strength (0.125% set), 1000 psi[e]	2.8	—	—	—
FABRICATING PROPERTIES				
Casting Temp (chill), F	625	660	620	620
CORROSION RESISTANCE	Resistant to corrosion by the usual lubricants			
AVAILABLE FORMS	Small ingots and bars			
USES[f]	Bearings for light loads	Bearings for high loads and speeds. Diesel engines, automotive engines, steamships, various types of machines	Bearings for moderate loads and speeds	Bearings for light loads and speeds. Car journal bearings

[a]ASTM B 23-49.
[e]Chill cast.
[f]Light loads—under 1000 psi; moderate loads—1000 to 2000 psi; heavy loads—over 3000 psi. Surface speeds: low—to 10 fps; moderate—to 20 fps; high—above 30 fps. 2×10^7 cycles.

Titanium and Its Alloys

Type →	Unalloyed	3 Al–5 Cr	5 Al–2.5 Sn	6 Al–4V
COMPOSITION, %	Ti 99.0	Al 3.0, Cr 5.0	Al 5.0, Sn 2.5	Al 5.5–6.3, V 3.5–4.5
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.163	0.166	0.161	0.160
Melting Temp Range, F	3135	—	2822–3002	—
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	9.8	—	4.85	—
Coef of Ther Exp (68–1650 F), per °F	5.8×10^{-6}	6.1×10^{-6}	5.7×10^{-6}	5.8×10^{-6}
Spec Ht (212 F), Btu/lb/°F	0.130	—	0.131	—
Elec Res (68 F), microhm-cm	55.0	150	157.3	—
Magnetic Permeability (20 oersteds)	1.00005	—	1.00005	—
MECHANICAL PROPERTIES[a]				
Mod of Elast in Tension (200 F), psi	$15–15.5 \times 10^6$	—	15.5×10^6	—
Ten Str (68 F), 1000 psi				
Annealed	89–100	155	125	130–140
Heat Treated	—	—	—	170
Yld Str (68 F), 1000 psi				
Annealed	80–82	145	120	120–130
Heat Treated	—	—	—	150
Elong (in 2 in.), %				
Annealed (68 F)	15–22	13	18	10–13
Heat Treated	—	—	—	13
Red. of Area (68 F), %				
Annealed	40–45	35	40	25–40
Heat Treated	—	—	—	40
Hardness (Rockwell)				
Annealed	C30	C32	C30–35	C33–36
Heat Treated	—	—	—	C38
Impact Str (Charpy, 68 F), ft-lb	20–35	13	18–20	15–25
Endurance Limit (10^8 cycles), 1000 psi				
Bar (unnotched)	60–62	85	—	70
Bar (notched)	37[b]	—	—	35
Sheet (unnotched)	43	—	95	—
Sheet (notched)	—	—	36[c]	—
Mod of Rigidity (200 F), psi	5.63	—	—	—
Shear Str, 1000 psi	65	—	—	—
THERMAL TREATMENT				
Annealing Temp, F	850–1250	—	1500–1600	—
Stress Relieving Temp, F	700–1000	—	1000–1200	—
FABRICATING PROPERTIES				
Hot Working Temp Range, F	300–800	—	1000	—
Deep Drawing Temp, F	800	—	—	—
Forging Temp, F	1300–1600	—	1400–1900	—
Fusion Weldability	Yes	No	Yes[d]	Marginal
Formability (sheet, 78 F)[e]	High	Bar only	Intermediate	Intermediate
CORROSION RESISTANCE	Superior resistance to nitric acid, moist chlorine, chlorine solutions, chlorinated organic compounds and inorganic chloride solutions. Excellent resistance to sea water and most chloride salt solutions unchallenged by other structural metals. Resist impingement, pitting attack			
AVAILABLE FORMS	Sheet, strip, plate, tubing, billets, bar, wire	Bar, forgings	Sheet, strip, plate, billets, bar, wire	Bar, sheet, strip
USES	Military aircraft parts requiring corrosion resistance and high strength-to-weight ratio up to 800 F. Naval and marine applications; chemical, pharmaceutical and food processing and handling equipment; marine diesel engine mufflers; springs (high proportional limit and low modulus of elasticity), rivets, bolts, nuts, screws and fittings; ordnance and sporting equipment; orthopedic and orthodontic equipment			

[a]Annealed condition unless otherwise stated. [b]60-deg notch, 0.010-in. radius, k = 2.7. [c]k = 4.0.
[d]Some users report difficulty in producing welds without porosity; others do not.
[e]All titanium sheet is formed with considerably less difficulty at elevated temperatures. Forming can be accomplished at temperatures in the 500 to 1000 F range with no need for postforming surface treatment, provided time at temperature is short.

Titanium and Its Alloys—concluded

Type →	2.2 Fe–2.1 Cr–2.0 Mo	8 Mn	3 Mn–1.5 Al	4 Mn–4 Al
COMPOSITION, %	Cr 1.8–2.4, Fe 1.9–2.5, Mo 1.7–2.3	Mn 7.9	Al 1.5, Mn 3.0	Al 4.0, Mn 4.0
PHYSICAL PROPERTIES				
Density, lb/cu in.	—	0.170–0.172	0.168	0.163–0.165
Melting Temp Range, F	—	2730–2970	—	2822–3002
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	—	6.7	—	4.9
Coef of Ther Exp (68–1650 F), per °F	—	7.1×10^{-6}	—	$5.7–6.3 \times 10^{-6}$
Specific Heat (68 F), Btu/lb/°F	—	0.118	—	0.133
Elec Res (68 F), microhm-cm	79	90.7	—	146.1
Magnetic Properties	Nonmagnetic	Nonmagnetic	Nonmagnetic	Nonmagnetic
Magnetic Permeability (20 Oersteds)	—	1.00005	—	1.00005
MECHANICAL PROPERTIES[a]				
Mod of Elasticity in Tension (200 F), psi	—	15.9×10^6	15×10^6	15.9×10^6
Ten Str, 1000 psi	120–130	126–135	125	145–150
Yld Str, 1000 psi	110–115	118–120	116	135–142
Elong (in 2 in.), %	12–15	15–18	18	14–15
Red. of Area, %	25	32	—	35–40
Hardness (Brinell)	C30–34	C28–34	C26–32	C30–36
Impact Str (Charpy), ft-lb	—	—	15–20	11–15
Endurance Limit, 1000 psi				
Sheet (unnotched)	—	90	—	—
Bar (unnotched)	—	—	—	75–90
Bar (notched)	—	—	—	32[f]
Compr Yld Str, 1000 psi	—	120	—	—
Mod of Rigidity, psi	—	6×10^6	—	6.27×10^6
THERMAL TREATMENT				
Annealing Temp, F	—	900–1250	1250	1300
Stress Relieving Temp, F	—	<700 or at 1000	—	—
FABRICATING PROPERTIES				
Hot Working Temp Range, F	—	500–600	—	—
Forging Temp, F	—	—	1300–1700	1300–1750
Fusion Weldability[d]	No	No	Marginable	Questionable
Formability (sheet, 78 F)[e]	Intermediate	Intermediate	Moderate	Bar only
CORROSION RESISTANCE	Superior resistance to nitric acid, moist chlorine, chlorine solutions, chlorinated organic compounds, and inorganic chloride solutions. Excellent resistance to corrosive attack by sea water and most chloride salt solutions unchallenged by other structural metals. Resists impingement, pitting attack			
AVAILABLE FORMS	Sheet, strip, plate, wire, bar, extrusions	Sheet, strip, plate	Sheet, plate, billet, bar, wire	Billets, bar, forgings, plate, wire
USES	Military aircraft parts requiring corrosion resistance and high strength-to-weight ratio up to 800 F. Naval and marine applications; chemical, pharmaceutical and food processing and handling equipment; marine diesel engine mufflers; springs (high proportional limit and low modulus of elasticity), rivets, bolts, nuts, screws and fittings; ordnance and sporting equipment; orthopedic and orthodontic equipment			

[a]Annealed condition unless otherwise stated.
[d]Some users report difficulty in producing welds without porosity; others do not.
[e]All titanium sheet is formed with considerably less difficulty at elevated temperatures. Forming can be accomplished at temperatures in the 500 to 1000 F range with no need for postforming surface treatment, provided time at temperature is short.
[f]k = 3.9.

Uranium and Thorium

Metal →	Uranium	Thorium
PHYSICAL PROPERTIES		
Density, lb/cu in.	0.69	0.42
Melting Point, F	2071	3074
Ther Cond (70 F), Btu/hr/sq ft/°F/ft	14.5	21.4
Coef of Ther Exp, per °F	12.1 x 10^{-6} [a]	6.2 x 10^{-6} [b]
Specific Heat, Btu/lb/°F	0.03	0.03
Electrical Resistivity (68 F), microhm-cm	25–50	18
MECHANICAL PROPERTIES		
Mod of Elast in Tension psi	30 x 10^6	10 x 10^6
Tensile Strength (annealed), 1000 psi	90	37.5
Yield Strength (0.2% offset, annealed), 1000 psi	25	27
Elongation (in 2 in., annealed), %	13	40
FABRICATING PROPERTIES		
Workability	Can be forged, rolled, swaged and drawn. Heating must be done in a protective atmosphere	Can be readily hot or cold worked. Fabricated by forging, rolling, swaging, extruding or drawing
Machinability	Moderately difficult to machine	Can be machined like mild steel with or without cutting fluids
Joining	Can be welded or brazed in protective atmosphere or vacuum	Difficult to weld. Brazing yields brittle joints
CORROSION RESISTANCE	Very poor resistance to atmosphere, water and most reagents	
AVAILABLE FORMS	Shapes which have been produced include plate, rod, tube, wire and foil	Shapes which have been produced include rod, sheet, thin-walled tube, fine wire, foil
USES	Fissionable material (fuel) in nuclear reactor	Secondary (breeder) reactor fuel

[a] 70-250 F, parallel to A axis; 0.8 x 10^{-6} parallel to B axis; 12.9 x 10^{-6} parallel to C axis.
[b] 70 F.

Zinc Alloys

Type ➡	Commercial Rolled Zinc (deep drawing)	Commercial Rolled Zinc	Commercial Rolled Zinc	Copper Hardened Rolled Zinc Alloy	Rolled Zinc Alloy
COMPOSITION, %	Pb 0.10 max, Zn bal	Pb 0.05–0.10, Cd 0.05–0.08, Zn bal	Pb 0.25–0.50, Cd 0.25–0.45, Zn bal	Cu 0.85–1.25, Zn bal	Cu 0.85–1.25, Mg 0.006–0.016, Zn bal
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.258	0.258	0.258	0.259	0.259
Melting Point, F	786	786	786	792	792
Ther Cond (64 F), Btu/hr/sq ft/°F/ft	62.2	62.2	—	—	60.5
Coef of Ther Exp, per °F					
With Grain	18.1×10^{-6}	18.1×10^{-6}	18.8×10^{-6}	—	19.3×10^{-6}
Across Grain	12.8×10^{-6}	12.8×10^{-6}	13.0×10^{-6}	—	11.7×10^{-6}
Spec Ht (68–212 F) Btu/lb/°F	0.094	0.094	0.094	0.0957	0.0957
Elec Res (68 F), microhm-cm					
Hot Rolled	6.06	—	—	6.22	6.31
Cold Rolled	6.10	—	—	—	—
MECHANICAL PROPERTIES					
Ten Str, 1000 psi[a]					
Hot Rolled	19.5, 23	21, 25	23, 29	24, 30	29, 40
Cold Rolled	21, 27	22, 29	25, 31	31, 40	36, 46
Elong (in 2 in.), %[a]					
Hot Rolled	65, 50	52, 30	50, 32	50, 35	20, 10
Cold Rolled	50, 40	40, 30	45, 28	44, 30	25, 10
Hardness (Brinell)					
Hot Rolled	38	43	47	52	61
Cold Rolled	—	—	—	60	80
Endurance Limit (hot rolled), 1000 psi	2.5	3.8	4.1	6.1	6.8
FABRICATING PROPERTIES					
Hot Working Temp Range, F	248–527	248–527	248–437	447–572	447–572
Melting Range, F	887–977	887–977	887–977	887–977	887–977
Ingot Casting Range, F	815–905	815–905	815–905	815–905	815–905
Annealing Temp, F	—	—	221	347	347
Machinability	Good	Good	Good	Good	Good
Joining					
Torch Welding	Poor to fair	Poor to fair	Poor to fair	Poor to fair	Poor to fair
Single Impulse Resistance Welding	Poor	Poor	Poor	Poor	Poor
Multiple Impulse Resistance Welding	Fair to good	Fair to good	Fair to good	Fair to good	Fair to good
Soldering	Good	Good	Good	Good	Good
Common Processes	Drawing, bending, roll forming				
	Spinning, swaging, impact extrusion		Swaging, impact extrusion	Spinning, swaging	
CORROSION RESISTANCE	Excellent resistance to both metropolitan and rural atmospheric corrosion (penetration in in. per yr is 0.000064 in Palmerton, Pa., and 0.00028 in New York City); also hot soapy water, printing inks, trichloroethylene, carbon tetrachloride, dry illuminating gas, and moisture- and acid-free hydrocarbons. Fair resistance to pure ethyl and methyl alcohols, glycerine, water, petroleum products. Poor resistance to steam, spray insecticides, animal oils, strong acids and bases, and mixtures of glycerine or alcohol and water				
AVAILABLE FORMS	Rolled strip and sheet; extruded rod and shapes; drawn rod and wire				
USES	Drawn battery cans, eyelets, grommets, laundry tags, address plates, flashing		Soldered battery cans, photoengravers' and lithographers' sheets	Weatherstrip, nameplates, ferrules. Drawn, formed or spun parts requiring stiffness	Corrugated roofing, flat, drawn or moderately formed parts requiring maximum stiffness
	Drawn, formed or spun parts not requiring stiffness	Drawn, formed or spun parts requiring some rigidity			

[a]Two values represent properties parallel to grain and perpendicular to grain, in that order.

Cast Zinc Alloys

Type →	Alloy XXIII[a]	Alloy XXV[a]	Slush Casting Alloy[b]	Slush Casting Alloy (unbreakable metal)[b]
COMPOSITION, %	Al 3.5–4.3, Mg 0.03–0.08, Zn[c] bal	Al 3.5–4.3, Cu 0.75–1.25, Mg 0.03–0.08, Zn[c] bal	Al 4.5–5.0, Cu 0.2–0.3, Zn[c] bal	Al 5.25–5.75, Zn[c] bal
PHYSICAL PROPERTIES				
Density, lb/cu in.	0.24	0.24	—	—
Melting Point, F	728	727	734	743
Ther Cond (158–284 F), Btu/hr/sq ft/°F/ft	65.3	62.9	—	—
Coef of Ther Exp (68–212 F), per °F	15.2×10^{-6}	15.2×10^{-6}	—	—
Spec Ht (68–212 F), Btu/lb/°F	0.10	0.10	—	—
Elec Res (68 F), microhm-cm	6.37	6.54	—	—
Solidification Shrinkage, %	1.17	1.17	—	—
MECHANICAL PROPERTIES[d]				
Ten Str, 1000 psi				
Die Cast	41	47.6	—	—
Chill Cast	—	—	28.0	25.0
Elong (in 2 in.), %				
Die Cast	10	7	—	—
Chill Cast	—	—	—	1
Hardness (Brinell, die cast)	82	91	—	—
Impact Str (Charpy), ft-lb				
Die Cast	43	48	—	—
Chill Cast	—	—	3	1
Endurance Limit (10^8 cycles), die cast, 1000 psi	6.875	8.175	—	—
Compr Yld Str (die cast), 1000 psi	60	87	—	—
Shear Str (die cast), 1000 psi	31	38	—	—
FABRICATING PROPERTIES				
Melting Temp Range, F	727.9–932.0	727.0–932.0	—	—
Die Casting Temp Range, F	740–800	740–800	—	—
Machinability	Good	Good	Good	Good
Joining				
Torch Welding	Poor to fair	Poor to fair	—	—
Single Impulse Resistance Welding	Poor	Poor	—	—
Multiple Impulse Resistance Welding	Fair to good	Fair to good	—	—
Soldering	Poor[e]	Poor[e]	—	—
Common Fabrication Processes	Welding, soldering, machining, riveting, spinning, cold swaging		Welding, soldering, machining	
CORROSION RESISTANCE	Excellent resistance to both metropolitan and rural atmospheric corrosion[f]; also hot soapy water, printing inks, trichloroethylene, carbon tetrachloride, dry illuminating gas, and moisture- and acid-free hydrocarbons. Fair resistance to pure ethyl and methyl alcohols, glycerine, water and petroleum products. Poor resistance to steam, spray insecticides, animal oils, strong acids and bases, and mixtures of glycerine or alcohol and water			
USES	Automotive parts, household utensils, office equipment, building hardware, padlocks, toys, novelties, drop hammer dies (XXV)		Slush and permanent mold castings, principally for lighting fixtures	

[a] ASTM B86-53T.
[b] Because of their limited use, few data are available on these alloys.
[c] Special high grade zinc is required.
[d] Based on a ¼-in. section for die cast alloys; a ½-in. section for chill cast alloys.
[e] Cadmium-zinc and lead-tin solders diffuse into the casting, promoting subsurface attack. Castings must be nickel plated to be joined by lead-tin solders.
[f] Penetration in in. per yr in Palmerton, Pa., and New York City, respectively, is 0.78×10^{-4} and 2.2×10^{-4} for XXIII, and 0.63×10^{-4} and 2.8×10^{-4} for XXV.

Zirconium, Hafnium and Vanadium

Metal →	Zirconium	Hafnium	Vanadium
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.24	0.47	0.23
Melting Point, F	3355	3400	3110
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	9.6	—	—
Coef of Ther Exp (70 F), per °F	3.1×10^{-6}	3.4×10^{-6}	4.8×10^{-6}
Specific Heat, Btu/lb/°F	0.069	0.035	0.12
Electrical Resistivity (68 F), microhm-cm	40	30[a]	25
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	14×10^6	20×10^6	20×10^6
Tensile Strength, 1000 psi			
Annealed	29[b], 59[c]	—	72
Cold Worked	82[b], 90[c]	—	113
Yield Strength, 1000 psi			
Annealed	11[b], 38[c]	—	64
Cold Worked	58[b], 84[c]	—	109
Elongation (in 2 in.), %			
Annealed	26[b], 27[c]	—	28
Cold Worked	1.5[b], 10[c]	—	3
Hardness (Rockwell)			
Annealed	B42[b], B91[c]	B78[d]	B81
Cold Worked	B87[b], B98[c]	—	B93
FABRICATING PROPERTIES			
Annealing Temperature, F	1550; heavy sections in air, light sections in vacuum or inert atmosphere	1380 in vacuum or inert atmosphere	1650 in vacuum or inert atmosphere
Workability	Similar to titanium	Hot worked at 1550 F; cold worked 30% between anneals	Good cold working properties
Machining	Similar to titanium	Similar to stainless steel	Tools similar to those for cold rolled steel
Joining	Can be arc or flash-butt welded under inert atmosphere	—	Can be welded with heliarc torch under argon
CORROSION RESISTANCE	Excellent resistance to hydrochloric acid in all concentrations. Resists dilute sulfuric acid, nitric acid in all concentrations, and alkalis. Attacked by aqua regia	Resistant to oxidizing acids but attacked by hydrofluoric acid	Resistant to sea water. Not affected by moderate concentration of hydrochloric and sulfuric acids. Dissolved by nitric acid of any strength
AVAILABLE FORMS	Sheet, rod, tubing, shapes	Has been produced in sheet and rod	Plate, strip, bars, sheet, wire
USES	Structural parts and fuel cladding in nuclear reactors. Probable future use: corrosion resisting equipment, particularly for handling hydrochloric acid	No applications have been developed	AEC classified applications

[a] 32 F.
[b] Iodide zirconium.
[c] Kroll zirconium, melted in graphite.
[d] As-deposited iodide hafnium.

Bob Rossi, Chief Engineer, tells
Roy Johnson, Plant Manager

"We switched to Formbrite —and saved 12 cents apiece!"

.032" gage 70-30 Formbrite is used for this 4½" diameter rearview mirror head shown full size. Strip is 5 13/32" wide supplied in heavy coils for long press runs. Copper, nickel and chromium plating on a solid brass base provides a bright, rustless, long-lasting outdoor finish.

Peerless Rearview Mirrors. "Flight-Wing," below, and the newer "Director" model, left. Housings and mounts are chromium-plated zinc-base die castings.

This easy-to-polish, superfine-grain drawing bra has been slashing finishing costs in plant after plan on all kinds of jobs. Now Peerless Accessories Co of Mount Holly, N. J., reports:

"To our line of lighting and safety automoti accessories, we've recently added two rearvie mirror assemblies. We had been using regular draw ing brass for the dished head until your represent tive persuaded us to try Formbrite. Here are t results, based on a very careful cost study:

Finishing procedure using regular drawing brass	Present procedure using Formbrite®
1) Grease grinding or "cutting"	Not necessary with Formbr
2) Buffing	Light buff
3) Copper strike	Copper strike
4) Nickel plate (.00045")	Bright nickel plate (.0003"
5) Buffing nickel	Not necessary
6) Chromium plate	Chromium plate
Cost 27¢ each	**Cost 15¢ each**

"That's a saving of 12 cents apiece. Multiply it 3,000 to 4,000 a day and it becomes important mone

*Formbrite's superfine grain made possible a lighter but equally serviceable plate of *bright* nickel

Surprisingly, Formbrite doesn't cost a penny mo Find out for yourself how its superfine grain, exc lent drawing properties, strength, and scratch resi ance can help you make a better product at low cost. Write for Publication B-39. Better yet, ask about a sample lot. The American Brass Compan Waterbury 20, Conn. In Canada: Anaconda Ame can Brass Ltd., New Toronto, Ontario.

Formbrite FINE-GRAIN DRAWING BR

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For more information, turn to Reader Service card, circle No. 428

DATA
SECTION

Properties of Materials

Plastics and Rubber

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Acrylics

Type →		Cast Resin Sheets, Rods		Moldings		
		General Purpose Type I[a]	General Purpose Type II[a]	Grade 5[b]	Grade 6[b]	Grade 8[b]
PHYSICAL PROPERTIES	ASTM					
Specific Gravity	D792...	1.18–1.19	1.18–1.19	1.18	1.18	1.19
Ther Cond, Btu/hr/sq ft/°F/ft	[c]	0.10–0.15	0.10–0.15	0.12	0.12	0.12
Coef of Ther Exp, 10^{-5} per °F	D696...	5	5	4	4	3
Spec Ht, Btu/lb/°F	.....	0.35	0.35	0.35	0.35	0.35
Refractive Index	D542...	1.485–1.500	1.485–1.495	1.489–1.493	1.489–1.493	1.489–1.493
Transmittance (luminous, 0.125 in.), %	D791...	91–92	91–92	>92	>92	>92
Haze, %	D672...	1–2	1–2	<3	<3	<3
Water Absorption (24 hr), %	D570...	0.3–0.4	0.2–0.4	0.4	0.4	0.3
Flammability (0.125 in.), ipm	D635...	0.5–2.5	0.5–2.5	0.9–1.2	0.9–1.2	0.9–1.2
MECHANICAL PROPERTIES						
Mod of Elast in Tension, 10^5 psi	D638...	3.5–4.5	4.0–5.0	3.5–4.5	4.0–5.0	4.0–5.0
Ten Str, 1000 psi	D638...	6–8	8–10	8–9.5	9–10	9–10.5
Elong (in 2 in.), %	D638...	2–7	2–7	3–5	3–5	3–5
Hardness (Rockwell)	D785...	M90–100	M96–102	M80–88	M84–95	M92–103
Impact Str (Izod notched), ft-lb/in.	D256...	0.5	0.4	0.3–0.5	0.3–0.4	0.3–0.4
Mod of Elast in Flex, 10^5 psi	D790...	3.5–4.5	4.0–5.0	3.5–4.5	4.0–5.0	4.0–5.0
Flex Str, 1000 psi	D790...	12–14	15–17	15	15–16	16
Compr Yld Str (0.1% offset), 1000 psi	D695...	10–12	12–14	14.5	15	17
ELECTRICAL PROPERTIES						
Vol Res, ohm-cm	D257...	$>10^{15}$	$>10^{15}$	$>10^{14}$	$>10^{14}$	$>10^{15}$
Dielec Str (short time), v/mil	D149...	450–500	450–500	400–500	400–500	400–500
Dielec Const						
60 Cycles	D150...	3.5–4.5	3.5–4.5	2.3–3.9	2.3–3.9	2.2–3.5
10^6 Cycles	D150...	2.7–3.2	2.7–3.2	2.3–2.9	2.3–2.9	2.2–2.7
Dissip Factor						
60 Cycles	D150...	0.05–0.06	0.05–0.06	—	—	—
10^6 Cycles	D150...	0.02–0.03	0.02–0.03	0.03	0.03	0.02–0.03
Arc Resistance, sec	.....	No track	No track	No track	No track	No track
FABRICATING PROPERTIES						
Bulk Factor		—	—	1.8–2.2	1.8–2.2	1.8–2.2
Injection Molding						
Pressure, 1000 psi		—	—	15–25	15–25	20–30
Temperature, F		—	—	350–425	375–450	400–475
Hot Forming Temp, F		250–320	280–340	—	—	—
Extruding Temp, F		—	—	350–400	375–425	400–450
HEAT RESISTANCE						
Max Rec Svc Temp, F		140–160	180–200	155	165	190
Heat Dist Temp, F		150–170	190–210	166	176–180	196–202
CHEMICAL RESISTANCE		Resist weak alkalis, acids and aliphatic hydrocarbons. Attacked by esters, ketones, aromatic hydrocarbons, chlorinated hydrocarbons and concentrated acids				
USES		Transparent aircraft enclosures, radio and television parts, lighting, drafting equipment, signs		Decorative and functional automotive parts, reflectors, protective goggle lenses, radio and television parts, household appliance parts		

[a]ASTM D702-46. [b]ASTM D788-48T. [c]Cenco-Fitch.

Alkyds

Type ➡		General Purpose	Electrical	High Strength
PHYSICAL PROPERTIES	ASTM			
Specific Gravity	D792...	2.22–2.24	2.16–2.18	2.00–2.08
Ther Cond, Btu/hr/sq ft/°F/ft	.....	0.35–0.60	0.35–0.60	0.20–0.30
Coef of Ther Exp, per °F	D696...	1–3 x 10^{-6}	1–3 x 10^{-5}	1–3 x 10^{-6}
Water Absorption (24 hr), %	D570...	0.08–0.10	0.04–0.06	0.07–0.10
Flammability, ipm	.....	Not self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES				
Tensile Strength, 1000 psi	D651...	3–4	3–4	6–10
Impact Strength (Izod notched), ft-lb/in. notch	D256...	0.30–0.35	0.30–0.35	8–12
Mod of Elast in Flexure, psi	D790...	22–27 x 10^5	22–27 x 10^5	22–28 x 10^5
Flexural Strength, 1000 psi	D790...	7–10	7–10	14–17
Compressive Strength, 1000 psi	D690...	16–20	18–20	24–28
ELECTRICAL PROPERTIES				
Volume Resistivity, ohm-cm	D257...	10^{14}	10^{14}	10^{14}
Dielectric Strength (step by step), v/mil	D149...	300–350	300–350	300–350
Dielectric Constant				
60 Cycles	D150...	6.0–6.5	6.0–6.5	5.2–6.0
10^6 Cycles	D150...	4.8–5.0	4.2–4.5	4.0–4.5
Dissipation Factor				
60 Cycles	D150...	0.050–0.060	0.035–0.040	0.02–0.03
10^6 Cycles	D150...	0.016–0.018	0.014–0.015	0.017–0.022
FABRICATING PROPERTIES				
Bulk Factor	D954...	1.95–2.15	1.85–2.05	9–11
Compression Molding				
Pressure, 1000 psi	.....	1.0–1.5	1.0–1.5	1.5–2.0
Temperature, F	.....	270–330	270–330	270–330
HEAT RESISTANCE				
Max Rec Svc Temp (limited periods), F	.....	350	300	350
Heat Dist Temp (264 psi), F	D648...	350–400	350–400	>400
CHEMICAL RESISTANCE		Resistant to weak acids; attacked by alkalis; practically unattacked by organic liquids such as alcohols, hydrocarbons and fatty acids		
USES		Ignition parts, fuse blocks, switch and circuit breaker covers and bases, molded resistors and capacitors, television tuner segments		

Cellulose Acetate

Type →		Type I —Medium[a]	Type II—Hard[a]			Type III —Soft[a]
			H6	H4	H2	
PHYSICAL PROPERTIES	ASTM					
Specific Gravity	D792...	1.27–1.34	1.29–1.34	1.28–1.34	1.27–1.34	1.27–1.34
Ther Cond, Btu/hr/sq ft/°F/ft	C177...	0.10–0.19	0.10–0.19	0.10–0.19	0.10–0.19	0.10–0.19
Coef of Ther Exp, 10^{-5} per °F	D696...	4.4–9.0	4.4–9.0	4.4–9.0	4.4–9.0	4.4–9.0
Refractive Index	D542...	1.46–1.50	1.46–1.50	1.46–1.50	1.46–1.50	1.46–1.50
Spec Ht, Btu/lb/°F	.....	0.3–0.42	0.3–0.42	0.3–0.42	0.3–0.42	0.3–0.42
Transmittance (luminous), %	D791...	80–90	75–90	75–90	80–90	80–95
Haze, %	D672...	3–10	4–15	4–15	4–10	3–8
Water Absorption (24 hr), %	D570...	2.2–5.7	2.0–3.5	1.9–3.6	2.2–5.3	2.3–6.5
Flammability, ipm	D635...	0.5–2.0	0.5–2.0	0.5–2.0	0.5–2.0	—
MECHANICAL PROPERTIES						
Ten Str, 1000 psi	D638...	2.7–6.5	6–8.5	5.4–7.6	4.6–6.7	1.9–4.7
Elong (in 2 in.), %	D638...	18–47	6–31	12–35	17–40	32–50
Hardness (Rockwell)	D785...	R72–115	R112–123	R106–121	R101–119	R49–103
Impact Str (Izod notched), ft-lb/in.	D256...	1.1–4.0	0.4–1.9	0.6–2.3	0.7–2.7	2.0–5.2
Mod of Elast in Flex, 10^5 psi	.....	1.1–3.5	2.6–4.0	2.3–3.4	1.9–3.3	0.9–2.5
Compr Str, 1000 psi	D695...	14.5–25	25–36	22–33	19–28	13–20
ELECTRICAL PROPERTIES						
Vol Res, ohm-cm	D257...	10^{10}–10^{13}	10^{10}–10^{13}	10^{10}–10^{13}	10^{10}–10^{13}	10^{10}–10^{13}
Dielec Str (short time), v/mil	D149...	250–365	250–365	250–365	250–365	250–365
Dielec Const						
60 cycles	D150...	3.5–7.5	3.5–7.5	3.5–7.5	3.5–7.5	3.5–7.5
10^6 Cycles	D150...	3.2–7.0	3.2–7.0	3.2–7.0	3.2–7.0	3.2–7.0
Dissipation Factor						
60 Cycles	D150...	0.03–0.38	0.03–0.38	0.03–0.38	0.03–0.08	0.03–0.08
10^6 Cycles	D150...	0.03–0.33	0.03–0.33	0.03–0.33	0.03–0.33	0.03–0.33
FABRICATING PROPERTIES						
Bulk Factor		2.0–2.6	2.0–2.6	2.0–2.6	2.0–2.6	2.0–2.6
Compression Moulding						
Pressure, 1000 psi		500–5000	500–5000	500–5000	500–5000	500–5000
Temperature, F		280–350	350–420	330–390	320–370	260–310
Injection Molding						
Pressure, 1000 psi		8–32	8–32	8–32	8–32	8–32
Temperature, F		355–440	420–490	410–480	390–460	335–395
Extruding Temp, F		355–400	420–450	405–455	390–420	335–365
HEAT RESISTANCE		As these are thermoplastic materials, they gradually become softer as the temperature rises. Maximum service temperature depends on such factors as formula, design of part, humidity and service conditions				
CHEMICAL RESISTANCE		Unattacked by water, salt water solutions, white gasoline, oleic acid, 5% acetic acid and dilute sulfuric acid. Decomposed by 30% sulfuric, 10% nitric and 10% hydrochloric acids; sodium hydroxide; and 10% ammonium hydroxide. Dissolved by acetone and ethyl acetate				
USES		Automotive and radio knobs, tool handles, business machine keys. Electrical items such as fluorescent lamp supports, coil spools and contact bases. Toys and novelties, sun glass goggles and frames, spectacle frames, buttons and tags				

[a]ASTM D706-55T

Cellulose Acetate Butyrate and Cellulose Propionate

Type →		Cellulose Acetate Butyrate			Cellulose Propionate[b]
		Type I[a] (Medium)	Type II[a] (Hard)	Type III[a] (Soft)	
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792	1.16-1.24	1.19-1.25	1.15-1.22	1.18-1.24
Ther Cond, Btu/hr/sq ft/°F/ft	C177	10-19 x 10^{-2}	10-19 x 10^{-2}	10-19 x 10^{-2}	10-19 x 10^{-2}
Coef of Ther Exp (max), per °F	D696	6-9 x 10^{-5}	6-9 x 10^{-5}	6-9 x 10^{-5}	7-9 x 10^{-5}
Refractive Index	D542	1.46-1.49	1.46-1.49	1.46-1.49	1.46-1.48
Spec Ht, Btu/lb/°F		0.3-0.4	0.3-0.4	0.3-0.4	0.3-0.4
Transmittance (luminous), %	D791	80-90	75-90	85-95	80-90
Haze, %	D672	3-10	5-15	3-8	5-10
Water Absorption (24 hr), %	D570	1.3-2.1	1.5-2.2	1.1-2.1	1.2-2.0
Flammability, ipm[c]	D635	0.5-1.5	0.5-1.5	0.5-1.5	1.0-1.5
MECHANICAL PROPERTIES					
Ten Str, 1000 psi	D638	2.9-5.7	5.0-6.8	1.9-3.8	1.5-7.5
Elong, %		47-66	38-54	60-74	50-60
Hardness (Rockwell)		R79-112	R108-114	R59-95	R20-120
Impact Str (Izod notched), ft-lb/in.	D256	1.0-4.3	0.6-2.4	2.5-5.4	0.8-11.0
Mod of Elast in Flex, 1000 psi		93-168	148-199	74-126	160-330
Flex Str, 1000 psi		No break	No break	No break	No break
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257	10^{10}-10^{12}	10^{10}-10^{12}	10^{10}-10^{12}	10^{12}-10^{15}
Dielec Str (short time), v/mil	D149	250-400	250-400	250-400	300-450
Dielec Const					
60 Cycles	D150	3.5-6.4	3.5-6.4	3.5-6.4	—
10^6 Cycles	D150	3.2-6.2	3.2-6.2	3.2-6.2	3.4-3.6
Dissipation Factor					
60 Cycles	D150	0.01-0.04	0.01-0.04	0.01-0.04	—
10^6 Cycles	D150	0.01-0.04	0.01-0.04	0.01-0.04	0.02-0.03
FABRICATING PROPERTIES					
Bulk Factor		2.0-2.4	2.0-2.4	2.0-2.4	1.6-2.0
Compressive Molding					
Pressure, 1000 psi		0.5-5	0.5-5	0.5-5	—
Temperature, F		285-340	320-390	265-305	—
Injection Molding					
Pressure, 1000 psi		8-32	8-32	8-32	8-32
Temperature, F		355-440	390-480	335-395	310-480
Mold Shrinkage, in./in.		0.001-0.008	0.001-0.009	0.001-0.006	0.002-0.006
HEAT RESISTANCE					
Heat Dist Temp, F					
66 psi	D648	156-197	188-233	139-164[1]	130-200
264 psi	D648	130-172	158-210	121-137	—
CHEMICAL RESISTANCE		Unaffected by 30% sulfuric, 5% acetic, 10% hydrochloric and oleic acids; discolored by 10% nitric acid. Unaffected by 1% sodium hydroxide and 2% sodium carbonate; slightly softened by 10% sodium hydroxide and discolored by 10% ammonium hydroxide. Unaffected by white gasoline, but swollen or dissolved by ethyl alcohol, acetone, ethyl acetate, ethylene dichloride, carbon tetrachloride and toluene. Unaffected by water, salt water and 3% hydrogen peroxide.			
USES		Telephone handsets, steering wheels, automobile white-wall disks, film spools, irrigation tubing, radio housings. Electrical items such as fluorescent light supports, coil spools and contact bases.			Pen and pencil parts. Other uses similar to those of b tyrate.

[a] ASTM D707-55T.
[b] Values given are for compounds having different plasticizer contents.
[c] Self-extinguishing cellulose acetate butyrate compounds are available.

5 Plastics & Rubber

Cellulose Nitrate and Ethyl Cellulose

Type ➡		Cellulose Nitrate Sheet	Ethyl Cellulose Moldings		
			General Purpose	High Impact	
				A	B
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792	1.35-1.40	1.10-1.16	1.10-1.16	1.10-1.16
Ther Cond, Btu/hr/sq ft/°F/ft	Cenco-Fitch	0.133	0.092-0.167	0.092-0.167	0.092-0.167
Coef of Ther Exp, per °F	D696	4.4-6.6 x 10^{-5}	5.5-11 x 10^{-5}	5.5-11 x 10^{-5}	5.5-11 x 10^{-5}
Refractive Index	D542	1.49-1.51	1.47	1.47	1.47
Transmittance (luminous), %	D791	89-92[a]	—	—	—
Haze, %	D672	2.0-4.0[a]	—	—	—
Water Absorption (24 hr), %	D570	1.0-2.0	1.2-2.0	0.8-2.0	1.0-2.0
Flammability (>0.050 in.), ipm	D635	[b]	0.5-1.5	0.5-1.5	0.5-1.5
MECHANICAL PROPERTIES					
Mod of Elast in Tension, 10^5 psi	D638	1.9-2.2	0.5-3.5	1.0-3.0	1.0-3.0
Ten Str, 1000 psi	D638	7-8	3-7	4-6.5	3-5
Strain at Fracture, %	D638	40-50	—	—	—
Hardness (Rockwell)	D785	R95-115	R80-120	R80-90	R70-80
Impact Str (Izod notched), ft-lb/in.	D758	5-7	1.7-6.0	3.5-6.0	4.0-7.0
Mod of Elast in Flex, 10^5 psi	D790	2.3-2.5	—	—	—
Flex Str, 1000 psi	D790	9-11[c]	4-10	6	4
Compr Str, 1000 psi	D695	22-35	—	—	—
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257	10-15 x 10^{10}	10^{12}-10^{14}	10^{12}-10^{14}	10^{12}-10^{14}
Dielec Str (short time), v/mil	D149	300-600	350-500	350-500	350-500
Dielec Const					
60 Cycles	D150	7.0-7.5	—	—	—
10^6 Cycles	D150	6.4	2.8-3.5	2.8-3.3	3.0-3.6
Dissipation Factor					
60 Cycles	D150	0.09-0.12	—	—	—
10^6 Cycles	D150	0.06-0.09	0.010-0.060	0.010-0.030	0.018-0.035
FABRICATING PROPERTIES					
Bulk Factor		—	1.8-2.4	1.8-2.4	1.8-2.4
Compression Molding					
Pressure, 1000 psi		—	0.5-5	0.5-5	0.5-5
Temperature, F		—	250-390	250-390	250-390
Injection Molding					
Pressure, 1000 psi		—	6-32	8-32	8-32
Temperature, F		—	350-500	350-500	350-500
Hot Forming Temperature, F		135-250	—	—	—
Extruding Temperature, F		180-200	300-450	350-450	350-450
HEAT RESISTANCE					
Max Rec Svc Temp, F		120-140	—	—	—
Heat Dist Temp, F					
66 Psi		200-220	—	—	—
264 Psi		140-160	120-160	130-145	125-140
CHEMICAL RESISTANCE		Resistant to 30% sulfuric acid, carbon tetrachloride, 10% sodium chloride, 10% nitric acid, 10% hydrochloric acid, 5% acetic acid, 2% sodium tetrachloride, distilled water, aliphatic and aromatic hydrocarbons, and <1% sodium hydroxide. Soluble in ketones, esters, lower alcohols and glycol ethers. Attacked by concentrated sodium hydroxide, ethylene dichloride and 50% ethanol		Unaffected by 3 sulfuric, 5 acetic and 10% hydrochloric acids; 10% sodium hydroxide, 2% sodium carbonate and water. Slightly affected by 30 sulfuric and 10% nitric acids; and 10% ammonium hydroxide. Attacked by 95% ethyl alcohol, acetone, toluene and gasoline	
USES		Fountain pens, spectacle frames, drawing instruments, ping-pong and billiard balls		Radio housings, toothbrushes, pen and pencil barrels, tool handles	

[a] 1/8 in. sheet containing no color.
[b] Cellulose nitrate under 0.050 in. thick burns very rapidly (D568).
[c] No break; specimen failed by slipping through supports.

Diallyl Phthalate

Type ➡		Orlon-Filled	Dacron-Filled	Asbestos-Filled	Glass Fiber-Filled
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792...	1.31–1.34	1.40	1.65–1.70	1.55–1.59
Coef of Ther Exp, per °F	D696...	1.5 x 10^{-5}	2.0 x 10^{-5}	3.5 x 10^{-5}	2.2–2.6 x 10^{-5}
Water Abs (122 F, 48 hr), %	.....	0.2–0.5	0.2	0.4–0.5	0.12–0.2
Flammability (ignition time), sec	.....	68	84–90	70	400–450
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi[a]	D638...	6 x 10^5	—	17 x 10^5	—
Ten Str, psi	D638...	4500–6000	4600	4000–5500	5500–7000
Hardness (Rockwell)	D785...	M108	—	M107	M100
Impact Str (Izod notched), ft-lb/in.	D256...	0.5–1.2	1.7–4.5	0.30–0.45	0.5–6.0
Flex Str, 1000 psi	D790...	10–10.5	9–11.5	8–10	10–12
Compr Str, 1000 psi	D695...	20–30	30	18–25	25
ELECTRICAL PROPERTIES					
Dielec Str, v/mil					
Short Time (dry)	D149...	366	376–390	378	382–430
Short Time (wet[b])	D149...	375	360–391	330	345–420
Step by Step (dry)	D149...	364	350–374	320–350	335–420
Step by Step (wet[b])	D149...	333	350–361	225–250	295–420
Dielectric Breakdown, kv					
Short Time (dry)	.....	55–81.7	70–80	55–80	63–70
Short Time (wet[b])	.....	60–65	66–70	55	45–65
Step by Step (dry)	.....	55–60.5	60–65	38–70	60–65
Step by Step (wet[b])	.....	46–60	60	39–60	49.5–65
Dissip Factor[c]					
Dry	D150...	0.023, 0.015	0.006, 0.012	0.039, 0.040	0.004, 0.010
Wet[d]	D150...	0.026, 0.020	0.009, 0.017	0.042, 0.154	0.008, 0.015
Dielec Const[c]					
Dry	D150...	3.9, 3.3	3.8, 3.4	5.2, 4.5	4.5, 4.2
Wet[d]	D150...	4.1, 3.3	3.8, 3.6	4.8, 4.7	4.6, 4.4
Vol Res, megohm-cm[d]	D257...	60,000	100–25,000	6000	1000
Surface Res, megohms[d]	D257...	25,000	500–10,000	6000	500
Arc Resistance, sec	D495...	85–115	105–125	125–140	125
FABRICATING PROPERTIES					
Bulk Factor	D392...	3.5–5.2	5.2	1.9–2.4	1.9–4.0
Compression Molding					
Pressure, psi	.....	500–2000	500–2000	500–2000	500–2000
Temperature, F	.....	270–320	270–320	270–320	270–320
Transfer Molding					
Pressure, psi	.....	1000–5000	1000–5000	1000–5000	1000–5000
Temperature, F	.....	270–310	270–310	270–310	270–310
Mold Shrinkage, in./in.	.....	0.009	0.010	0.004–0.007	0.004
Post Mold Shrinkage (480 hr, 257 F), in./in.	.....	0.001	0.0006	0.0005	0.0005–0.0007
HEAT RESISTANCE					
Max Rec Svc Temp, F	.....	300	300–370	350–450	400–450
Heat Dist Temp, F	D648...	240–266	270–290	300–350	300–350
CHEMICAL RESISTANCE		Unaffected by weak acids and alkalis and organic solvents. Slightly affected by strong acids and alkalis			

[a]Conditioned 48 hr at 122 F.
[b]Tested after 48-hr immersion in water at 122 F.
[c]Values given for frequencies of 1 kc and 1 mc, in that order.
[d]Conditioned 30 days at 100% RH and 158 F.

Cast Epoxies

Type →		Epoxy	Polysulfide-Epoxy
PHYSICAL PROPERTIES	ASTM		
Specific Gravity	D638...	1.15–1.19	1.15–1.23
Ther Cond, Btu/hr/ sq ft/°F/ft	C177...	0.097–0.116	—
Coef of Ther Exp, per °F	D696...	2.66–5.00 x 10^{-5}	1.1–5.5 x 10^{-5}
Water Absorption (24 hr), %	D570...	0.05–0.12	0.25–0.50
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	D638...	4.5–5.4 x 10^5	0.01–3.5 x 10^5
Tensile Strength, 1000 psi	D638...	8.5–12	3–10
Elongation (in 2 in.),%	D638...	—	0–100
Hardness (Rockwell)	D785...	M80–105	—
Impact Strength (Izod notched), ft-lb/in	D256...	0.35–0.7	2–10
Flexural Strength, 1000 psi	D790...	14.5–18.5	1–18
Compressive Strength, 1000 psi	D695...	15.5–23.5	1–14
ELECTRICAL PROPERTIES			
Volume Resistivity, ohm-cm	D257...	>8 x 10^{12}	1.3–15 x 10^{12}
Dielectric Strength (short time), v/mil	D149...	400–500	235–400
Dielectric Constant			
60 Cycles	D150...	3.7–4.1	2.5–4.5
10^6 Cycles	D150...	3.4–3.8	3–6
Dissipation Factor			
60 Cycles	D150...	0.001–0.002	0.010–0.040
10^6 Cycles	D150...	0.020–0.026	0.018–0.090
Arc Resistance, sec	D495...	50–180	50–180
HEAT RESISTANCE			
Max Rec Svc Temp, F		300	250–300
Heat Dist Temp (264 psi), F		150–225	150–250
CHEMICAL RESISTANCE		Resistant to weak acids and some strong acids. Slightly affected by some strong alkalis. Practically unattacked by organic liquids such as alcohols and hydrocarbons	
USES		Tools and dies, potting and encapsulation of electrical components, preparation of precision castings. High-strength laminates,structural adhesives, patching compounds	

Fluorocarbons

Type ➡		Polytrifluorochloro-ethylene	Polytetrafluoro-ethylene
PHYSICAL PROPERTIES	ASTM		
Specific Gravity	D792...	2.10–2.15	2.1–2.3
Ther Cond, Btu/hr/sq ft/°F/ft	[a]	0.035–0.036	0.142
Coef of Ther Exp, per °F	D696...	3.88×10^{-5}	5.5×10^{-5}
Refractive Index	D542...	1.43	1.35
Specific Ht, Btu/lb/°F	.....	0.22	0.25
Transmittance (luminous), %	D791...	80–92	—
Water Absorption (24 hr), %	D570...	0.00	0.00
Flammability	.....	Nonflammable	Nonflammable
MECHANICAL PROPERTIES			
Mod of Elast in Compression, psi	D638...	1.8×10^5	$0.70–0.90 \times 10^5$
Mod of Elast in Tension, psi	D638...	$1.9–3.0 \times 10^5$	$0.38–0.65 \times 10^5$
Tensile Strength, 1000 psi	D638...	4.6–5.7	1.5–3.0
Elongation (in 2 in.), %	D638...	28–87	120–350
Hardness (Rockwell)	D785...	R110–115	J75–95
Abrasion Resistance, gm/cycle	[b]	0.0080	—
Impact Strength (Izod notched), ft-lb/in.	D256...	3.50–3.62	2.5–4.0
Mod of Elast in Flexure, psi	D747...	$2.0–2.5 \times 10^5$	0.6×10^5
Flexural Strength (0.1% offset), 1000 psi	D790...	—	1.6
Compressive Strength (0.1% offset), 1000 psi	D695...	2.0	0.7–1.8
ELECTRICAL PROPERTIES			
Volume Resistivity, ohm-cm	D257...	10^{18}	10^{19}
Dielectric Strength (short time), v/mil	D149...	530–600	400–500
Dielectric Constant			
60 Cycles	D150...	2.6–2.7	2.0
10^6 Cycles	D150...	2.30–2.37	2.0
Dissipation Factor			
60 Cycles	D150...	0.02	0.0002
10^6 Cycles	D150...	0.007–0.010	0.0002
Arc Resistance, sec	.....	>360	>200
FABRICATING PROPERTIES			
Injection Molding			
Pressure, 1000 psi	.....	5–30	—
Temperature, F	.....	420–620	—
Compression Molding			
Pressure, 1000 psi	.....	0.1–15	—
Temperature, F	.....	445–525	—
Bulk Factor	.....	2.5	—
Mold Shrinkage, in./in.	.....	0.005–0.010	—
HEAT RESISTANCE			
Max Rec Svc Temp, F	.....	380	500
Heat Dist Temp, F			
66 Psi	D648...	196–291	—
264 Psi	D648...	151–178	—
CHEMICAL RESISTANCE		Impervious to corrosive chemicals; highly resistant to most organic solvents. Swelling may occur with some highly halogenated and aromatic compounds	Inert to most chemicals and solvents with the exception of alkali metals. Halogenated solvents at high temperatures and pressure have some effect
USES		Chemical pipes, gaskets, pump parts, electrical cables, tank linings, connectors, coil forms, connector inserts, valve diaphragms, electrical insulation	Chemical pipes, valves and valve liners, gaskets and packings, pump bearings and impellers, electrical and electronic equipment, anti-adhesive coatings

[a] Cenco-Fitch.
[b] Federal Spec L-P-406A #1092.1.

Melamines

Filler and Type →		Alpha Cellulose—General Purpose	Mineral—Electrical	Fabric—Low to Intermediate Shock Resistant	Fabric—Intermediate Resistance
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792...	1.47–1.52	1.7–2.0	1.5	1.5
Ther Cond, Btu/hr/sq ft/°F/ft	.....	0.17–0.24	0.32–0.41	0.257	0.25–0.26
Coef of Ther Exp, per °F	D696...	1.11–3.17 x 10^{-5}	1.06–2.50 x 10^{-5}	1.55 x 10^{-5}	1.55 x 10^{-5}
Transmittance (luminous), %	D570...	14.5	Opaque	Low	—
Water Absorption (24 hr), %	D570...	0.1–0.6	0.08–0.14	0.3–0.6	0.2–1.3
Flammability	.....	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	D638...	13–16 x 10^5	16–19.5 x 10^5	16 x 10^5	16 x 10^5
Ten Str, 1000 psi	D638...	7–10	5.5–7.0	8–9.5	5.7–9
Elong (in 2 in.), %	D638...	—	0.30–0.45	0.6–0.8	0.6
Hardness (Rockwell)	D785...	M118–124, E110	M110	M120	M115
Impact Str (Izod notched), ft-lb/in.	D256...	0.24–0.35	0.28–0.40	0.5–0.9	1.0–1.5
Mod of Elast in Flex, psi	D790...	15 x 10^5	16 x 10^5	18.5 x 10^5	19 x 10^5
Compr Str, 1000 psi	D695...	40–45	25–30	30–35	25–32
Flex Str, 1000 psi	D790...	10–16	8.7–11	12–15	13–17
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257...	10^{12}–10^{14}	10^{11}–10^{13}	10^9–10^{12}	—
Dielec Str (short time), v/mil	D149...	310–330	350–430	250–350	130–370
Dielec Const					
60 Cycles	D150...	8.4–9.4	6.4–10.2	7.6–8.6	10.5–15.5
10^6 Cycles	D150...	5.6–5.8	6.1–6.7	6.5–6.9	6.1–6.7
Dissip Factor					
60 Cycles	.....	0.05–0.08	0.07–0.17	0.07–0.11	0.10–0.32
10^6 Cycles	.....	0.03–0.04	0.04–0.05	0.036	0.050–0.065
Arc Resistance, sec	D495...	122–128	120–170	115–128	5–8
FABRICATING PROPERTIES					
Bulk Factor	D392...	2.1–3.1	2.1–2.5	5–10	5–10
Compression Molding					
Pressure, 1000 psi	.....	1.5–8	1–7	4–8	4–8
Temperature, F	.....	280–370	275–340	275–330	300–380
Transfer Molding					
Pressure, 1000 psi	.....	4–12	4–20	—	—
Temperature, F	.....	300–320	270–340	—	—
Mold Shrinkage, in./in.	.....	0.006–0.015	0.003–0.007	0.003–0.004	0.004–0.005
HEAT RESISTANCE					
Max Rec Svc Temp, F	.....	210	250–400	250	250
Heat Dist Temp (264 psi), F	D648...	350–410	265	310	375
CHEMICAL RESISTANCE		Resistant to weak acids, weak alkalis, organic solvents, greases and oils. Attacked by strong acids and strong alkalis			
USES		General purpose electrical and mechanical applications such as kitchenware, tableware, lighting fixtures, reflectors	Elevated temperature and electrical applications such as ignition parts, circuit breakers, terminal blocks, electronic parts	Applications requiring improved impact strength, such as insulation, circuit breakers, food trays, medical equipment	Applications requiring medium impact strength, such as nozzles, insulation

Melamines—concluded

Filler and Type →		Unfilled	Cellulose—Electrical	Glass Fiber	Alpha Cellulose and Mineral
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792...	1.48	1.43–1.50	1.9–2.0	1.49
Ther Cond, Btu/hr/sq ft/°F/ft	.....	—	0.17–0.20	0.28	—
Coef of Ther Exp, per °F	D696...	—	$1.11–2.78 \times 10^{-5}$	0.82×10^{-5}	—
Transmittance (luminous), %	.....	Good	Opaque	—	—
Water Absorption (24 hr), %	D570...	0.3–0.5	0.27–0.80	0.10–0.60	0.5
Flammability	D570...	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	D638...	—	$10–11 \times 10^5$	—	—
Ten Str, 1000 psi	D638...	—	5–9	6–10	5
Elong (in 2 in.), %	D638...	—	0.6	—	—
Hardness (Rockwell)	D785...	—	M115–125	—	—
Impact Str (Izod notched), ft-lb/in.	D256...	—	0.27–0.36	4.0–12.0	0.30
Mod of Elast in Flex, psi	D790...	13×10^5	$1.0–1.3 \times 10^5$	—	—
Compr Str, 1000 psi	D695...	40–45	25–33.5	26–32	—
Flex Str, 1000 psi	D790...	11–14	9–10	10–23	8
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257...	—	$10^{12}–10^{13}$	$1–7 \times 10^{11}$	10^{12}
Dielec Str (short time), v/mil	D149...	—	350–400	250–300	375
Dielec Const					
60 Cycles	D150...	—	6.2–7.6	9.7–11.1	—
10^6 Cycles	D150...	—	4.7–7.0	6.9–7.2	6.4
Dissip Factor					
60 Cycles	.....	—	0.019–0.033	0.14–0.23	—
10^6 Cycles	.....	—	0.032–0.06	0.02–0.03	0.031
Arc Resistance, sec	D495...	100–145	95–135	180–186	125
FABRICATING PROPERTIES					
Bulk Factor	D392...	2.0	2.2–2.6	5–7	2.4
Compression Molding					
Pressure, 1000 psi	.....	2–5	1.5–3	2–8	2–5
Temperature, F	.....	300–340	290–360	280–340	280–350
Transfer Molding					
Pressure, 1000 psi	.....	—	6–20	8–20	2–10
Temperature, F	.....	—	300–330	290–310	285–350
Mold Shrinkage, in./in.	.....	0.011–0.012	0.006–0.008	0.001–0.004	0.006–0.007
HEAT RESISTANCE					
Max Rec Svc Temp, F	.....	210	250–280	300–400	275–325
Heat Dist Temp (264 psi), F	D648...	293–298	265	400	300
CHEMICAL RESISTANCE		Resistant to weak acids, weak alkalis, organic solvents, greases and oils. Attacked by strong acids and strong alkalis			
USES		Pearlescent buttons, moldings, ornamental applications	General mechanical and electrical applications, particularly at elevated temperatures. Applications requiring improved holding power for metallic inserts such as electrical and electronic parts	Applications requiring high shock resistance, good electrical properties, and high resistance to burning. Switchgear, terminal strips, stand-off insulators, coil forms	Primarily electrical applications requiring low after-shrinkage, good dimensional stability and excellent molding characteristics

Polyamides (Nylons)

Type →		66 Nylon			610 Nylon	
		General Purpose Injection Molding		Extrusion and Injection Molding	Extrusion and Injection Molding	
		0.2% Water	2.5% Water		0.2% Water	1.5% Water
PHYSICAL PROPERTIES	ASTM					
Specific Gravity	D792...	1.14	—	1.14	1.09	—
Ther Cond, Btu/hr/sq ft/°F/ft	[a]	0.14	—	0.142	0.12	—
Coef of Ther Exp, 10^{-5} per °F	D696...	5.5	—	5.5	5.5	—
Spec Ht, Btu/lb/°F	.....	0.3–0.5	—	0.4	0.3–0.5	—
Refractive Index	D542...	1.53	—	—	1.53	—
Water Absorption (24 hr), %	D570...	1.5	—	1.5	0.4	—
Flammability	D757...	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES						
Mod of Elast in Tension, 10^5 psi	D638...	4.1	2.1	4.0	2.8	1.6
Ten Str, 1000 psi	D638...	11.8	11.2	11.2–12.6	8.5	7.1
Elong (in 2 in.), %	D638...	60	300	100–200	85	320
Hardness (Rockwell)	D785...	M79, R118	M59, R108	R118	R111	—
Impact Str (Izod notched), ft-lb/in.	D256...	0.9	2.0	1.1–1.5	0.6	1.6
Mod of Elast in Flex, 10^5 psi	D790...	4.1	2.1	—	2.8	1.6
Flex Yld Str, 1000 psi	D790...	13.8	—	13.8	8	—
Compr Yld Str, 1000 psi	D695...	13	—	—	7.2	—
Compr Yld Str (1% def), 1000 psi	D695...	—	—	4.9	—	—
ELECTRICAL PROPERTIES						
Vol Res, ohm-cm	D257...	—	—	4.5×10^{13}	—	—
Dielec Str (short time), v/mil	D149...	385	—	385	470	—
Dielec Const						
60 Cycles	D150...	4.0	7.6	4.1	3.9	—
10^6 Cycles	D150...	3.6	3.6	3.4	—	—
Dissip Factor						
60 Cycles	D150...	0.01	0.09	0.014	—	—
10^6 Cycles	D150...	0.02	0.08	0.04	0.02	—
Arc Resistance, sec	D495...	—	—	—	—	—
FABRICATING PROPERTIES						
Bulk Factor	D392...	2.1	—	2.14	2.2	—
Injection Molding						
Pressure, 1000 psi	.....	10–20	—	—	10–20	—
Temperature, F	.....	520–650	—	—	450–600	—
Joining	.....	Can be cemented with aqueous phenol or various proprietary adhesives. Spin welding, extrusion lamination and other techniques can be used in special cases				
HEAT RESISTANCE						
Max Rec Svc Temp, F	.....	275–300	—	—	225	—
Heat Dist Temp, F						
66 Psi	D648...	—	—	360	—	—
264 Psi	D648...	—	—	150	—	—
CHEMICAL RESISTANCE		Inert to most organic chemicals such as esters, ketones, alcohols and hydrocarbons. Resists alkalis and salt solutions, but is attacked by phenols, formic acid, mineral acid and strong oxidizing agents				
USES		Gears, bearings, automatic washing machine valves, rollers and slides, combs and brush backs, aerosol bottles, coil forms, and mechanical parts where lubrication is undesirable or difficult		Tubing, rods, pipe, sheeting, laminations	Jacketing for wire and cable; special molded parts	

[a] Cenco-Fitch.

Polyamides (Nylons)—concluded

Type →		6 Nylon		Soluble Resin (solution, injection, extrusion)	Glass Fiber–Filled
		General Purpose Injection Molding	Extrusion and Injection Molding		
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792...	1.13–1.14	1.14	1.12–1.13	1.33
Ther Cond, Btu/hr/sq ft/°F/ft	[a]	0.10–0.14	0.11–0.12	0.16	—
Coef of Ther Exp, 10^{-5} per °F	D696...	4.6–5.4	4.6–7.1	8.2	Very low
Spec Ht, Btu/lb/°F	.....	0.4	—	0.4	—
Refractive Index	D542...	—	—	—	—
Water Absorption (24 hr), %	D570...	1.6–2.0	2.1–3.3	2.0–5.5	0.2–1.2
Flammability	D757...	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES					
Mod of Elast in Tension, 10^5 psi	D638...	2.5–3.4	1.5–3.6	0.38	—
Ten Str, 1000 psi	D638...	10.2–12	10.2–11.3	3.8–7.4	12–20
Elong (in 2 in.), %	D638...	300	300	300–600	6.5–8.5
Hardness (Rockwell)	D785...	R105–118	R103–111	R45–83	M85–95
Impact Str (Izod notched), ft-lb/in.	D256...	1.2–3.0	1.5–3.5	>16	2.0
Mod of Elast in Flex, 10^5 psi	D790...	—	—	0.3–0.7	—
Flex Yld Str, 1000 psi	D790...	15.5	—	1–2	>25
Compr Yld Str, 1000 psi	D695...	11–12	—	—	—
Compr Yld Str (1% def), 1000 psi	D695...	7.1–9.7	6.7–8.8	0.8	—
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257...	10^{13}–10^{15}	10^{13}–10^{15}	5×10^{13}	$4.9–5.7 \times 10^{15}$
Dielec Str (short time), v/mil	D149...	420–485	440–500	420	487–520
Dielec Const					
60 Cycles	D150...	4.5–11.5	5.1–14.0	10.7	3.99–4.03
10^6 Cycles	D150...	3.6–4.3	3.5–4.5	4.5	3.37–3.45
Dissip Factor					
60^6 Cycles	D150...	0.03–0.07	0.06–0.10	0.19	0.0155–0.0210
10^6 Cycles	D150...	0.03–0.13	0.03–0.11	0.14	0.0171–0.0176
Arc Resistance, sec	D495...	—	—	—	147–149
FABRICATING PROPERTIES					
Bulk Factor	D392...	1.60–1.68	1.72–1.82	2.5	2.0
Compression Molding					
Pressure, 1000 psi	.....	—	—	1–2	—
Temperature, F	.....	—	—	325–380	—
Injection Molding					
Pressure, 1000 psi	.....	10–25	—	10–25	10–25
Temperature, F	.....	440–550	—	300–500	450–700
Extruding Temp, F	.....	450–550	430–550	500–550	—
Joining	.....	Nylon adhesive or aqueous phenol		[b]	—
HEAT RESISTANCE					
Max Rec Svc Temp, F	.....	225–250	200–250	140	300–400
Heat Dist Temp, F					
66 Psi	D648...	340	—	100	350
264 Psi	D648...	145	—	—	—
CHEMICAL RESISTANCE		Resists esters, ketones, alkalis, weak acids, alcohols and common solvents. Not resistant to conc mineral acids	Resists petroleum oils and greases, alkalis, esters, ketones, alcohols and common solvents. Not resistant to mineral acids,	Resists ketones, alkalis and esters. Not resistant to alcohols, phenols, formic acid, and mineral acids	Attacked by strong acids. Fairly resistant to strong alkalis. Resists common solvents
USES		Bearings, gears, bushings, coil forms, brush backs, rod, tubing, tape	Abrasion-resistant shielding on insulated wire and mechanical cable. Pipe, tubing	Jacketing for wire and cable, seals, packings. sheeting, adhesives, abrasion-resistant finishes	Gears, business machine parts, appliance handles, terminal blocks, meter housings

[a] Cenco-Fitch.
[b] Can be bonded with 70-30 methanol-water as cement, or 10% solution of resin in methanol-water as solvent.

Phenolics

Type and Filler ➡		General—Woodflour and Flock	Shock—Paper, Flock or Pulp	High Shock—Chopped Fabric or Cord	Very High Shock—Glass Fiber
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792...	1.32–1.55	1.34–1.46	1.36–1.43	1.75–1.90
Ther Cond, Btu/hr/sq ft/°F/ft	C177...	0.097–0.170	0.1–0.16	0.097–0.170	—
Coef of Ther Exp, 10^{-5} per °F	D696...	1.66–2.50	1.6–2.3	1.60–2.22	0.88
Spec Ht, Btu/lb/°F	D570...	0.35–0.40	—	0.30–0.35	0.28–0.32
Water Absorption (24 hr), %	D635...	0.3–0.8	0.4–1.5	0.4–1.75	0.1–1.0
Flammability	.....	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES					
Mod of Elast in Tension, 10^5 psi	D638...	8–13	8–12	9–14	30–33
Ten Str, 1000 psi	D638, D651...	6.5–8.5	5.0–8.5	5–9	5–10
Elong (in 2 in.), %	D638...	0.4–0.8	—	0.37–0.57	0.2
Hardness (Rockwell)	D785...	M108–120	—	M93–120	M95–100
Impact Str (Izod notched), ft-lb/in.	D256...	0.24–0.50	—	0.6–8.0	10–33
Mod of Elast in Flex, 10^5 psi	.....	8–12	—	9–13	—
Flex Str, 1000 psi	D570...	8.5–12	8.0–11.5	8–15	10–45
Compr Str, 1000 psi	D695...	22–36	24–35	15–30	17–30
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257...	10^9–10^{13}	1–50 x 10^{11}	>10^{10}	7–10 x 10^{12}
Dielec Str (short time), v/mil	D149...	200–425	250–350	200–350	200–370
Dielec Const					
60 Cycles	D150...	5.0–9.0	5.6–11.0	6.5–15.0	7.1–7.2
10^6 Cycles	D150...	4.0–7.0	4.5– 7.0	4.5– 7.0	4.6–6.6
Dissip Factor					
60 Cycles	D150...	0.05–0.30	0.08–0.35	0.08–0.45	0.02–0.03
10^6 Cycles	D150...	0.03–0.07	0.03–0.07	0.03–0.09	0.02
Arc Resistance, sec	D495...	5	5	5	60
FABRICATING PROPERTIES					
Bulk Factor	.....	2.1–4.4	2.3–5.7	3.0–18.0	6.1–6.3
Compression Molding					
Pressure, 1000 psi	.....	1.5–5.0	2–5	2–6.5	1–5
Temperature, F	.....	290–380	290–380	280–380	500–5000
Transfer Molding					
Pressure, 1000 psi	.....	2–10	2–10	2–12	—
Temperature, F	.....	275–340	275–340	275–340	—
Mold Shrinkage, in./in.	.....	0.005–0.008	0.004–0.009	0.002–0.009	0.0
HEAT RESISTANCE					
Max Rec Svc Temp, F	.....	300–350	300	250–275	350–450
Heat Dist Temp, F	D648...	260–340	290–340	250–340	600
CHEMICAL RESISTANCE		Severely attacked by strong acids and strong alkalis. Effects of dilute acids, alkalis and organic solvents vary with the reagent. Chemical resistance varies with the particular formulation and not all materials of a type are equally resistant			
USES		Mechanical applications include pulleys, wheels, motor housings, handles. Electrical uses include coil forms, ignition parts, condenser housings, fuse blocks, instrument panels. Thermal applications include handles, appliance connector plugs. Chemical uses include photographic development tanks, rayon spinning buckets and parts, milking machine cups. Decorative uses include radio and television cabinets, handles, knobs, buttons			

Phenolics—continued

Type and Filler ➡		High Frequency—Mineral	Shock & Heat—Mineral, Flour and Yarn	Heat—Minera	Chemical (no filler)
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792...	1.75–1.92	1.68–2.00	1.54–1.75	1.24–1.90
Ther Cond, Btu/hr/sq ft/°F/ft	C177...	0.24–0.34	0.19–0.39	0.19–0.39	—
Coef of Ther Exp, 10^{-5} per °F	D696...	1.05–1.44	0.83–1.17	1.17	2.4
Spec Ht, Btu/lb/°F	D570...	0.28–0.32	0.28–0.32	0.28–0.32	—
Water Absorption (24 hr), %	D635...	0.01–0.07	0.1–0.5	0.2–0.5	0.15–0.60
Flammability	.....	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES					
Mod of Elast in Tension, 10^5 psi	D638...	30–50	15–25	10–20	7–15
Ten Str, 1000 psi	D638, D651...	5–7	4–9	4–6.5	4.5–7.5
Elong (in 2 in.), %	D638...	0.10–0.53	—	—	—
Hardness (Rockwell)	D785...	M100–110	M100–110	M98–115	M105–120
Impact Str (Izod notched), ft-lb/in.	D256...	0.30–0.38	0.27–3.50	0.24–0.40	0.2–0.6
Mod of Elast in Flex, 10^5 psi	.....	30–40	10–25	10–20	7–15
Flex Str, 1000 psi	D570...	8–12	7–15	3–10.5	7–12
Compr Str, 1000 psi	D695...	15–25	15–25	15–35	18–32
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257...	10^{13}	10^{10}–10^{12}	10^{11}–10^{12}	10^{1} –10^{12}
Dielec Str (short time), v/mil	D149...	300–375	100–250	150–350	225–275
Dielec Const					
60 Cycles	D150...	4.7–5.5	30–150	5.8–40.0	9–19
10^6 Cycles	D150...	4.4–5.1	5–7	4.8– 8.0	5.5–7.0
Dissip Factor					
60 Cycles	D150...	0.01–0.07	0.25–0.50	0.10–0.35	0.15–0.25
10^6 Cycles	D150...	0.005–0.02	0.10–0.50	0.04–0.15	0.04–0.09
Arc Resistance, sec	D495...	16	6	5–120	—
FABRICATING PROPERTIES					
Bulk Factor	.....	2.1–2.7	3–14	2.0–2.8	1.9–3.0
Compression Molding					
Pressure, 1000 psi	.....	2.0–5.5	2–6	2–6	2–6
Temperature, F	.....	300–350	290–380	290–380	300–360
Transfer Molding					
Pressure, 1000 psi	.....	2–10	2–12	2–9	2–10
Temperature, F	.....	275–325	275–325	275–325	275–340
Mold Shrinkage, in./in.	.....	0.003	0.0005–0.005	0.002–0.006	0.002–0.01
HEAT RESISTANCE					
Max Rec Svc Temp, F	.....	250–300	350–400	375–425	300–425
Heat Dist Temp, F	D648...	230–325	290–375	350–400	300–350
CHEMICAL RESISTANCE		Severely attacked by strong acids and strong alkalis. Effects of dilute acids, alkalis and organic solvents vary with the reagent. Chemical resistance varies with the particular formulation and not all materials of a type are equally resistant			
USES		Mechanical applications include pulleys, wheels, motor housings, handles. Electrical uses include coil forms, ignition parts, condenser housings, fuse blocks, instrument panels. Thermal applications include handles, appliance connector plugs. Chemical uses include photographic development tanks, rayon spinning buckets and parts, milking machine cups. Decorative uses include radio and television cabinets, handles, knobs, buttons			

continued

Phenolics—concluded

Type and Filler →		Arc Resistant—Mineral	Rubber Phenolic—Woodflour or Flock	Rubber Phenolic—Chopped Fabric	Rubber Phenolic—Asbestos
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792...	1.8–3.0	1.24–1.35	1.30–1.35	1.60–1.65
Ther Cond, Btu/hr/sq ft/°F/ft	C177...	0.24–0.34	0.12	0.05	0.04
Coef of Ther Exp, 10^{-5} per °F	D696...	—	0.83–2.20	1.7	2.2
Spec Ht, Btu/lb/°F	D570...	0.28–0.32	0.33	—	—
Water Absorption (24 hr), %	D635...	0.2	0.5–2.0	0.5–2.0	0.10–0.50
Flammability	.....	Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES					
Mod of Elast in Tension, 10^5 psi	D638...	—	4–6	3.5–6	5–9
Ten Str, 1000 psi	D638, D651...	6	4.5–9	3.5	4
Elong (in 2 in.), %	D638...	—	0.75–2.25	—	—
Hardness (Rockwell)	D785...	—	M40–90	M57	M50
Impact Str (Izod notched), ft-lb/in.	D256...	0.32	0.34–1.0	2.0–2.3	0.3–0.4
Mod of Elast in Flex, 10^5 psi	.....	—	4–6	3.5	5.0
Flex Str, 1000 psi	D570...	10	7–12	7	7
Compr Str, 1000 psi	D695...	20	12–20	10–15	10–20
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257...	6×10^{12}	10^6–10^{11}	10^{11}	10^{11}
Dielec Str (short time), v/mil	D149...	380	250–375	250	350
Dielec Const					
60 Cycles	D150...	7.4	9–16	15	15
10^6 Cycles	D150...	—	5	5	5
Dissip Factor					
60 Cycles	D150...	—	0.15–0.60	0.5	0.15
10^6 Cycles	D150...	0.10	0.1–0.2	0.09	0.13
Arc Resistance, sec	D495...	180	7–20	10–20	5–20
FABRICATING PROPERTIES					
Bulk Factor	.....	2.4	2.5–4.0	4.6–8.0	2.5
Compression Molding					
Pressure, 1000 psi	.....	2–5	2–6	2–6	2–6
Temperature, F	.....	285–350	300–360	300–350	300–350
Transfer Molding					
Pressure, 1000 psi	.....	2–10	2–12	2–12	2–12
Temperature, F	.....	285–350	300–350	300–350	300–350
Mold Shrinkage, in./in.	.....	0.004	0.005–0.010	0.003–0.006	0.005–0.008
HEAT RESISTANCE					
Max Rec Svc Temp, F	.....	400	212–300	212–225	225–260
Heat Dist Temp, F	D648...	335	220–270	220–280	250–300
CHEMICAL RESISTANCE		Severely attacked by strong acids and strong alkalis. Effects of dilute acids, alkalis and organic solvents vary with the reagent. Chemical resistance varies with the particular formulation and not all materials of a type are equally resistant			
USES		Mechanical applications include pulleys, wheels, motor housings, handles. Electrical uses include coil forms, ignition parts, condenser housings, fuse blocks, instrument panels. Thermal applications include handles, appliance connector plugs. Chemical uses include photographic development tanks, rayon spinning buckets and parts, milking machine cups. Decorative uses include radio and television cabinets, handles, knobs, buttons			

Cast Phenolics

Type →		Type I— Mechanical and Chemical	Type II— General Purpose Decorative	Type III— General Purpose Transparent
PHYSICAL PROPERTIES	ASTM			
Specific Gravity	D792...	1.31	1.32	1.33
Coef of Ther Exp, per °F	D696...	3.3–4.4 x 10^{-5}	3.3–5.5 x 10^{-5}	4.7–6.6 x 10^{-5}
Water Absorption (24 hr), %	D570...	0.35–0.40	0.32–0.35	0.3–2.0
Flammability (>0.050 in.)	D635...	Self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	D638...	4–5 x 10^5	3–4.5 x 10^5	1–3 x 10^5
Tensile Strength, 1000 psi	D638...	6–9	5–7.2	2.5–4.5
Hardness (Rockwell)	D785...	M93–120	M90–105	R98–120
Impact Strength (Izod notched), ft-lb/in	D256...	0.25–0.40	0.30–0.45	0.23–0.35
Mod of Elast in Flexure, psi	D790...	3–5 x 10^5	3–5 x 10^5	1–3 x 10^5
Flexural Strength, 1000 psi	D790...	11–17	10–15	4–7
Compressive Yield Strength (1% offset), 1000 psi	D695...	14–18	12.8–15.8	4.5–6.5
ELECTRICAL PROPERTIES				
Volume Resistivity, ohm-cm	D257...	1–7 x 10^{12}	1–3 x 10^{12}	3 x 10^{11}
Dielectric Strength (short time), v/mil	D149...	350–400	300–450	75–250
Dielectric Constant				
60 Cycles	D150...	6.5–7.5	15–20	20–30
10^6 Cycles	D150...	4.0–5.5	5.0–11.0	7–8
Loss Factor				
60 Cycles	D150...	0.05–0.9	0.4–4.0	5.0–17.0
10^6 Cycles	D150...	0.15–0.35	0.05–1.10	0.6–0.8
FABRICATING PROPERTIES	—	Castings produced by pouring resins into molds (generally made of lead). Resins converted to solid by heating several days at atmospheric pressure and temperatures below 212 F. After oven baking, casting is removed from mold, and is ready for machining and polishing		
HEAT RESISTANCE				
Heat Distortion Temp, F				
66 psi	D648...	—	150–160	125–135
264 psi	D648...	165–175	130–140	100–125
CHEMICAL RESISTANCE		Unless specially formulated, do not resist strong alkalis or strong acids. Dilute alkalis: slight to marked attack depending on alkali. Dilute acids: no effect or slight decomposition depending on acid. Continuous immersion in acetone, Cellosolve, methyl alcohol or ethyl alcohol results in noticeable attack, depending on time, temperature and hardness of cast resin		
USES		Drill and saw jigs, stretch press molds and dies for fabricating aircraft parts, furniture hardware, instrument casings, sporting goods, costume and ornamental jewelry		

Cast Allyls and Polyesters

Type ➡		Allyl	Rigid Polyester	Nonrigid Polyester
PHYSICAL PROPERTIES	ASTM			
Specific Gravity	D792...	1.30–1.45	1.12–1.46	1.06–1.25
Ther Cond, Btu/hr/sq ft/°F/ft	C177...	0.116–0.121	0.10–0.12	—
Coef of Ther Exp, per °F	D696...	2.8–5.6 x 10^{-5}	3.9–5.6 x 10^{-5}	—
Refractive Index	D542...	1.50–1.58	1.53–1.58	1.50–1.57
Specific Heat, Btu/lb/°F	.....	0.26–0.55	0.30–0.55	—
Water Absorption (24 hr), %	D570...	0.03–1.0	0.15–0.60	0.40–2.5
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	D638...	2–3 x 10^5	1.5–6.5 x 10^5	—
Tensile Strength, 1000 psi	D638...	4.5–7	4–10	0.9–1.9
Elongation (in 2 in.), %	D638...	—	<5	40–310
Hardness (Rockwell)	D785...	M92–118	M65–115	—
Impact Strength (Izod notched), ft-lb/in.	D256...	0.18–0.32	0.18–0.40	>7.0
Mod of Elast in Flexure, psi	.....	3–8 x 10^5	3–9 x 10^5	0.001–0.1 x 10^5
Flexural Strength, 1000 psi	D790...	6–14	7–19	—
Compressive Strength, 1000 psi	D695...	20–26	12–37	—
ELECTRICAL PROPERTIES				
Volume Resistivity, ohm-cm	D257...	>10^{13}	>10^{13}	>10^{12}
Dielectric Strength (short time), v/mil	D149...	330–500	340–570	220–400
Dielectric Constant				
60 Cycles	D150...	3.2–5.2	2.8–4.4	4.2–7.0
10^6 Cycles	D150...	3.3–4.8	2.8–4.0	3.7–6.1
Dissipation Factor				
60 Cycles	D150...	0.006–0.02	0.003–0.04	0.02–0.18
10^6 Cycles	D150...	0.024–0.045	0.006–0.04	0.02–0.06
Arc Resistance, sec	D495...	120–150	115–135	125–145
HEAT RESISTANCE				
Max Rec Svc Temp, F	D648...	300	250–300	200–250
Heat Dist Temp, F	.....	120–320	120–420	250
CHEMICAL RESISTANCE		Attacked by oxidizing acids. Slightly attacked by strong alkalis. Resistant to organic solvents	Slightly to heavily attacked by strong acids. Attacked by strong alkalis, ketones and chlorinated solvents	
USES		Castings used for aircraft glazing, electrical components, decorative applications. Resins used for premix and prepreg molding materials, matched metal molding and hand lay-up molding		

Polyethylenes

Type →	ASTM	Low Density: Melt Index 0.3-1.4	Low Density: Melt Index 1.7-3.6	Low Density: Melt Index 6-26	Low Density: Melt Index 200	High Density
PHYSICAL PROPERTIES						
Specific Gravity	D792	0.916–0.930	0.910–0.930	0.918–0.925	0.910	0.95–0.97
Ther Cond, Btu/hr/sq ft/°F/ft	C177	0.19	0.19	0.19	0.19	0.19
Coef of Ther Exp, 10^{-5} per °F	D696	8.9–11.0	8.9–11.0	8.9–11.0	11.0	6.9–11.0
Refractive Index	D542	1.51	1.51	1.51	1.51	1.51
Spec Ht, Btu/lb/°F	D570	0.53–0.55	0.53–0.55	0.53–0.55	0.53–0.55	0.53–0.55
Water Absorption (24 hr), %	D635	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Flammability, ipm		1.0	1.0	1.0	1.0	1.0
MECHANICAL PROPERTIES						
Mod of Elast in Tension, 10^5 psi	D638	0.21–0.27	0.24	0.20–0.24	—	—
Ten Str, 1000 psi	D412	1.9–2.5	1.4–2.4	1.4–2.0	0.9–1.1	3.5–5.5
Elong (in 2 in.), %	D412	550–725	500–700	125–675	80–100	25–100
Hardness (Shore)	D785	C73, D52	C73, D50–51	C73, D47–53	D45	D63–D70
Impact Str (Izod notched), ft-lb/in.	D256	—	—	—	—	1.0–3.0
Brittle Temp, F		< –94	< –94	< –4	< 14	< –100
Stiffness in Flex, 1000 psi	D747	14–24	13–27	12–30	10	55–70
Shear Str, 1000 psi		1.7–1.85	1.6–1.8	1.4–1.7	1	3.5–4.5
ELECTRICAL PROPERTIES						
Vol Res, ohm-cm	D257	10^{17}–10^{19}	10^{17}–10^{19}	10^{17}–10^{19}	10^{17}–10^{19}	10^{17}–10^{19}
Dielec Str (short time), v/mil	D149	550–1000	550–1000	550–1000	550–1000	550–1000
Dielec Const	D150	2.3	2.3	2.3	2.3	2.3
Dissip Factor	D150	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
FABRICATING PROPERTIES						
Bulk Factor		1.8–2.0	1.8–2.0	1.8–2.0	1.8–2.0	1.8–2.0
Compression Molding						
Pressure, 1000 psi		—	—	—	—	1.0–3.5
Temperature, F		—	—	—	—	300–450
Injection Molding						
Pressure, 1000 psi		5–22	5–22	5–15	2–10	5–22
Temperature, F		275–650	275–650	275–650	250–350	275–650
Mold Shrinkage, in./in.		0.02–0.05	0.02–0.04	0.01–0.04	0.01–0.02	0.02–0.05
Apparent (bulk) Density		30–33	30–33	30–33	30–33	—
HEAT RESISTANCE						
Softening Point, F		200–230	196–230	180–230	156	200
CHEMICAL RESISTANCE		Excellent resistance to acids and alkalis at normal temperatures, except oxidizing acids such as nitric, chlorosulfonic and fuming sulfuric. Insoluble in organic solvents below 122 F; at higher temperatures soluble to varying degrees in hydrocarbons and halogenated hydrocarbons, but insoluble in more polar liquids. Generally, a higher melt index material has greater solubility				
USES		Injection moldings: kitchen utility ware, toys, process tank liners, closures, packages, sealing rings, battery parts. Blow moldings: squeeze bottles for packaging, containers for drugs. Film: wrapping materials for food, clothes, other items. Wire and cable: high frequency insulation, jacketing. Pipe: chemicals handling, irrigation systems, natural gas transmission				Refrigerator parts, bouyancy applications, index packaging, structural housing panels, pipe insulation, cold storage insulation, toys

Silicones

Type and Filler →		General—Mineral	Improved Impact—Glass Fiber	High Impact—Glass Fiber
PHYSICAL PROPERTIES	ASTM			
Specific Gravity	D792...	1.8–2.0	1.8–2.0	1.65–2.00
Ther Cond, Btu/hr/sq ft/°F/ft	C177...	0.089–0.097	0.089–0.097	0.089–0.097
Coef of Ther Exp, per °F	D696...	2.78–3.23 x 10^{-5}	3.17–3.23 x 10^{-5}	0.45 x 10^{-5}
Water Absorption (24 hr), %	D570...	0.2–0.4	0.4–0.5	0.1–0.5
Flammability, ipm	D635...	0–78	0–60	25–100
MECHANICAL PROPERTIES				
Tensile Strength, 1000 psi	D651...	4–4.3	4–4.3	4.4–5
Hardness (Rockwell)	D785...	M89	M89	M45
Impact Strength (Izod notched) ft-lb/in	D256...	0.25–0.30	0.33–0.38	3.00–6.00
Mod of Elast in Flexure, psi	D790...	10–13 x 10^5	9–11 x 10^5	15–19 x 10^5
Flexural Strength, 1000 psi	D790...	6.8–7.5	6.1–6.4	9–14
Compressive Strength, 1000 psi	D695...	16–20	12–16	10–15
ELECTRICAL PROPERTIES				
Volume Resistivity, ohm-cm	D257...	>3.4 x 10^7	>3.4 x 10^7	>5 x 10^7
Dielectric Strength (short time), v/mil	D149...	350–400	300–400	250–400
Dielectric Constant				
60 Cycles	D150...	4.1–4.5	5.1–5.3	4.8–5.0
10^6 Cycles	D150...	3.8–4.3	4.9–5.1	3.6–5.1
Dissipation Factor				
60 Cycles	D150...	0.010–0.014	0.008–0.011	0.006–0.030
10^6 Cycles	D150...	0.006–0.010	0.007–0.011	0.005–0.020
Arc Resistance, sec	D495...	250–420	250–350	20–350
Loss Factor				
60 Cycles	D150...	0.041–0.063	0.041–0.058	0.029–0.035
10^6 Cycles	D150...	0.023–0.043	0.034–0.056	0.025–0.077
FABRICATING PROPERTIES				
Bulk Factor		2.1–2.6	2.3–2.8	6–9
Compression Molding				
Pressure, 1000 psi		2–4	2–4	1–5
Temperature, F		300–350	300–350	300–350
Transfer Molding				
Pressure, 1000 psi		3.5–15	3.5–15	4.5–15
Temperature, F		300–350	300–350	300–350
Mold Shrinkage, in./in.		0.006–0.010	0.005–0.008	0.003–0.005
HEAT RESISTANCE				
Max Res Svc Temp, F		>450	>450	>450
Heat Dist Temp, F	D648...	>300	>300	>300
CHEMICAL RESISTANCE		Resistant to aviation gasoline, lubricating oil, and sulfuric and hydrochloric acids. Slightly softened and pitted by sodium hydroxide, except some of the mineral-filled materials. Should be tested if resistance to ketones, toluene, ethylenes, etc., is required		
USES		Motor slot wedges, terminal boards, connector plugs, switches and insulators, aircraft brake assemblies, jet engine parts, aircraft ignition systems, guided missile parts		

Polystyrenes and Polymethylstyrenes

Type →		Methylstyrene		Polystyrene		
		Polymethyl-styrene	Methylstyrene-Acrylonitrile	General Purpose	Heat Resistant	Glass Fiber-Filled
PHYSICAL PROPERTIES	ASTM					
Specific Gravity	D792	1.03	1.06	1.04–1.07	1.04–1.07	1.32–1.35
Ther Cond, Btu/hr/sq ft/°F/ft	C177	—	—	0.058–0.080	0.058–0.080	—
Coef of Ther Exp, 10^{-5} per °F	D696	—	—	3.3–4.4	3.3–4.4	—
Spec Ht, Btu/lb/°F		—	—	0.32–0.35	0.32–0.35	—
Refractive Index	D542	1.581	1.559	1.58–1.60	1.58–1.60	Low
Transmittance (luminous), %		Transparent	Transparent	0–93	0–93	—
Water Absorption (24 hr), %	D570	0.05	0.31	0.03–0.05	0.03–0.07	0.07
Flammability, ipm	D635	Slow	Slow	1.0–1.5	1.0–1.5	—
MECHANICAL PROPERTIES						
Mod of Elast in Tension, 10^5 psi	D638	—	—	4–5	4–5	12
Ten Str, 1000 psi	D638	6.6	9.3	5–8	7–8.5	10–14.5
Elong (in 2 in.), %	D638	2.2	2.5	1.5–2.4	1.5–2.4	0.75–1.0
Hardness (Rockwell)	D785	M76	M83	M68–80	M65–85	M80–90
Impact Str (Izod notched), ft-lb/in.	D256	0.33	0.40	0.25–0.35	0.25–0.40	1.5–2.5
Mod of Elast in Flex, 10^5 psi		4.0	4.6	4–5	4–5	—
Flex Str, 1000 psi	D790	13	16	8–15	11–16	—
Compr Str, 1000 psi	D695	—	—	11.5–16	11.5–16	16–19
ELECTRICAL PROPERTIES						
Vol Res, ohm-cm	D257	2.63×10^{14}	2.65×10^{11}	10^{18}–10^{19}	10^{18}–10^{19}	0.1–6.7×10^{15}
Dielec Str (short time), v/mil	D149	890	610	>500	>500	440–496
Dielec Const						
60 Cycles	D150	—	—	—	—	3.11–3.22
10^6 Cycles	D150	2.48	2.81	—	2.45–2.65	2.94–2.98
Dissip Factor						
60 Cycles	D150	—	—	—	—	0.0364–0.0490
10^6 Cycles	D150	0.0006	0.0078	—	0.0001–0.0005	0.0019–0.0025
Arc Resistance, sec	D495	—	—	—	—	95–109
FABRICATING PROPERTIES						
Bulk Factor		—	—	1.6–2.3	1.6–2.3	—
Compression Molding						
Pressure, 1000 psi		1–8	1–8	1–7.5	1–10	2–5
Temperature, F		300–375	300–375	275–400	275–400	275–350
Injection Molding						
Pressure, 1000 psi		10–30	10–30	10–24	10–24	15–20
Temperature, F		400–550	400–550	325–650	375–600	450–575
Mold Shrinkage, in./in.		0.0046	0.0035	0.002–0.008	0.002–0.008	0.001–0.005
Joining		Can be solvent welded with ethyl or butyl acetate, methylethyl ketone, cyclohexanone or trichloroethylene; also (polymethylstyrene) xylene or toluene. Better bonds obtained by adding ground resin granules to these solvents		—	—	—
HEAT RESISTANCE						
Max Rec Svc Temp, F		210	212	140–160	160–180	—
Heat Dist Temp, F	D648	213	215	165–190	182–206	218–230
CHEMICAL RESISTANCE		Same as polystyrenes	Resists aliphatic hydrocarbons, gasoline, essential oils, vegetable and mineral oils	Good resistance to alkalis, salts, lower alcohols, glycols, water. Fair resistance to mineral and vegetable oils. Soluble in aromatic and chlorinated hydrocarbons. Softened or attacked by higher alcohols, gasoline, strong oxidizing acids, chlorine and bromine waters		
USES		Radio cabinets, housewares and household utility parts, refrigerator parts, decorative lighting, packaging, electronic components	Same as polymethylstyrene. Also metering sight glasses, fan blades, combs, automotive interior parts, machine housings	Electrical parts, including storage battery cases, insulators, coil forms. Fluorescent light fixtures, rigid containers, instrument panels, light machine housings, nameplates, refrigerator parts, housewares, toys		Household utility, cases, meter housings, cabinet doors, storage drawers

Modified Polystyrenes

Type ➡		Heat & Chemical Resistant	Medium Impact	High Impact	Extra High Impact
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792...	1.05–1.11	1.05–1.07	1.04–1.08	1.01–1.08
Ther Cond, Btu/hr/sq ft/°F/ft	C177...	0.046–0.072	0.024–0.072	0.024–0.072	0.02–0.10
Coef of Ther Exp, per °F	D696...	3.8×10^{-5}	$3.3–4.4 \times 10^{-5}$	$3.6–4.7 \times 10^{-5}$	$4.7–9.9 \times 10^{-5}$
Refractive Index	D542...	1.58–1.60	—	—	—
Spec Ht, Btu/lb/°F	.....	0.32–0.35	0.30–0.35	0.30–0.35	0.33–0.38
Water Absorption (24 hr), %	D570...	0.1–0.3	0.03–0.07	0.04–0.08	—
Flammability, ipm	D635...	0.4–0.7	1–2	1–2	0.06–1.0
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	D638...	$4–6 \times 10^5$	$4.2–4.6 \times 10^5$	$3.3–4.5 \times 10^5$	$2.0–3.5 \times 10^5$
Ten Str, 1000 psi	D638...	10–11	3.5–6.8	3.5–6.5	3–4.5
Elong (in 2 in.), %	D638...	1–3	5.5–7.5	5–35	20–100
Hardness (Rockwell)	D785...	M78–88	M70–80	M30–55	M30–65
Impact Str (Izod notched), ft-lb/in	D256...	0.25–0.50	0.6–1.0	1.0–3.0	4.8–15.0
Mod of Elast in Flex, psi	.....	$4–6 \times 10^5$	$3–5 \times 10^5$	$3–4.5 \times 10^5$	$2.5–4 \times 10^5$
Flex Str, 1000 psi	D790...	11–17	No failure	No failure	No failure
Compr Yld Str, 1000 psi	D695...	12–17	7–9	5–8.5	3.5–6.5
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257...	$10^{13}–10^{17}$	$10^{16}–10^{17}$	$10^{15}–10^{16}$	$10^{14}–10^{16}$
Dielec Str (short time), v/mil	D149...	400–600	>500	>450	>400
Dielec Const					
60 Cycles	D150...	2.7–3.4	2.55[a]	2.45–2.70[a]	2.55–2.93[a]
10^6 Cycles	D150...	2.7–3.1	—	—	—
Dissipation Factor					
60 Cycles	D150...	0.001–0.008	0.0004–0.0008[a]	0.0004–0.01[a]	0.007–0.1[a]
10^6 Cycles	D150...	0.001–0.008	—	—	—
FABRICATING PROPERTIES					
Bulk Factor	.....	1.6–2.3	1.6–2.3	1.6–2.3	—
Compression Molding					
Pressure, 1000 psi	.....	1–5	1–7.5	1–8	1–5
Temperature, F	.....	325–450	325–450	325–475	350–475
Injection Molding					
Pressure, 1000 psi	.....	10–24	10–24	10–24	10–24
Temperature, F	.....	400–700	300–600	350–600	375–525
Mold Shrinkage, in./in.	.....	0.002–0.008	0.002–0.008	0.002–0.008	0.005–0.009
HEAT RESISTANCE					
Max Rec Svc Temp, F	.....	175–190	140–165	125–165	125–155
Heat Dist Temp, F	D648...	200–220	160–180	155–175	150–165
CHEMICAL RESISTANCE		More resistant to attack by solvents, oils and other organic liquids than other polystyrenes	Similar to general purpose polystyrene		
USES		Battery cases, coil forms, drafting instruments, sight glasses on pressure lubricating systems, thermostat housings	Coat hangers, toilet seats, toys, novelties, containers, packaging	Refrigerator door panels, drawers and crispers; knobs, toys and novelties, vacuum forming sheets	Freezer lids, battery cases, action toys, children's furniture, tote boxes, trays

[a]Average for wide frequency range.

Ureas

Grade [a] ➡		1	2
PHYSICAL PROPERTIES	ASTM		
Specific Gravity	D792...	1.47–1.52	1.52
Ther Cond, Btu/hr/sq ft/°F/ft	C177...	0.17–0.244	—
Coef of Ther Exp, per °F	D696...	1.22–1.50 x 10^{-5}	—
Transmittance (luminous), %	.....	21.8	0
Water Absorption (24 hr), %	D570...	0.4–0.8	—
Flammability	D635...	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	D638...	13–16 x 10^5	—
Tensile Strength, 1000 psi	D638...	5–10	—
Elongation (in 2 in.), %	D638...	1.0	—
Hardness (Rockwell)	D785...	E94–97, M116–120	—
Impact Strength (Izod notched), ft-lb/in.	D256...	0.24–0.35	0.26–0.275
Flexural Strength, 1000 psi	D790...	10–18	10–13
Compressive Strength, 1000 psi	D695...	25–38	—
Shear Strength, 1000 psi	.....	11–12	—
ELECTRICAL PROPERTIES			
Volume Resistivity, ohm-cm	D257...	0.5–5 x 10^{11}	5–8 x 10^{10}
Dielectric Strength (short time), v/mil	D149...	300–400	340–370
Dielectric Constant			
60 Cycles	D150...	7.0–9.5	7.2–7.3
10^6 Cycles	D150...	6.4–6.9	6.4–6.5
Dissipation Factor			
60 Cycles	D150...	0.035–0.043	0.042–0.044
10^6 Cycles	D150...	0.028–0.032	0.027–0.029
Loss Factor			
60 Cycles	.....	0.24–0.38	0.30–0.32
10^6 Cycles	.....	0.18–0.22	0.17–0.19
Arc Resistance, sec	D495...	80–130	85–110
FABRICATING PROPERTIES			
Bulk Factor	.....	2.4–3.0	2.5
Compression Molding			
Pressure, 1000 psi	.....	2–8	2–5
Temperature, F	.....	275–350	275–320
Mold Shrinkage, in./in.	.....	0.006–0.014	0.007–0.008
HEAT RESISTANCE			
Heat Distortion Temperature, F	D648...	266–280	—
CHEMICAL RESISTANCE		High resistance to organic solvents, oils and greases. Poor resistance to acids and alkalis, depending on concentration	
USES		Such housings as radio, television, business machines, food equipment. Toilet seats, household electrical switches and plugs, buttons and cosmetic containers	Low cost items. Available only in dark color. Especially suited for electric switch plates, wiring devices and electrical parts requiring high arc resistance

[a] ASTM D-705-55.

Polyvinyl Chloride and Copolymers

Type →		Polyvinyl Chloride, Polyvinyl Chloride-Acetate			Vinylidene Chloride[a]
		Nonrigid—General	Nonrigid—Electrical	Rigid—Normal Impact	
PHYSICAL PROPERTIES	ASTM				
Specific Gravity	D792	1.20–1.55	1.16–1.40	1.32–1.44	1.68–1.75
Ther Cond, Btu/hr/sq ft/°F/ft	D325	0.07–0.10	0.07–0.10	0.07–0.10	0.053
Coef of Ther Exp, per °F	D696	—	—	$2.8–3.3 \times 10^{-5}$	8.78×10^{-5}
Refractive Index	D542	—	—	—	1.60–1.63
Spec Ht, Btu/lb/°F	D570	—	—	—	0.32
Water Absorption (24 hr), %	D635	0.2–1.0	0.40–0.75	0.03–0.40	>0.1
Flammability		Self-extinguishing	Self-extinguishing	Self-extinguishing	Self-extinguishing
MECHANICAL PROPERTIES					
Mod of Elast in Tension, 10^5 psi	D412	0.004–0.03	0.01–0.03	3.5–4.0[b]	0.7–2.0
Ten Str, 1000 psi	D412	1–3.5	2–3.2	5.5–9	4–8, 15–40
Elong (in 2 in.), %	D638	200–450	220–360	5–25	15–25, 20–30
Hardness (Rockwell)	D785	—	—	R117–120	M50–65
Hardness (Shore)	D676	A50–100	A78–100	D70–85	>A95
Impact Str (Izod notched), ft-lb/in.	D256	Variable	Variable	0.25–1.2	2–8, 0.053
Mod of Elast in Flex, psi	D790	—	—	$3.8–5.4 \times 10^5$	—
100% Modulus, psi		1300–1750	1200–2800	—	—
Flex Str, 1000 psi	D790	—	—	12.5–16	15–17, flexible
Compr Str, 1000 psi	D695	—	—	11–12	—
Compr Yld Str, 1000 psi	D695	—	—	10–11	75–85
Cold Flex Temp, F	D1043	−70 to 0	−7 to +59	—	—
Cold Bend Temp, F		−40 to −4	−49 to −4	—	—
ELECTRICAL PROPERTIES					
Vol Res, ohm-cm	D257	$1–700 \times 10^{12}$	$4–300 \times 10^{11}$	$10^{14}–>10^{16}$	$10^{14}–10^{16}$
Dielec Str (short time), v/mil	D149	—	24–500	725–1400	—
Dielec Const (60 cycles)	D150	5.5–9.1	6.0–8.0	2.3–3.7	3–5
Dissip Factor (60 cycles)	D150	0.05–0.15	0.08–0.11	0.020–0.03	0.03–0.15
Loss Factor (60 cycles)	D150	—	1.0–1.2	0.030–0.072	—
FABRICATING PROPERTIES					
Bulk Factor		2.4–2.6	2.4–2.6	2.0–2.4	—
Compression Molding					
Pressure, 1000 psi		0.5–2	0.5–2	>1	0.5–5
Temperature, F		285–350	285–350	275–400	250–350
Injection Molding					
Pressure, 1000 psi		7–15	12–20	>20	10–30
Temperature, F		320–350	325–375	300–375	300–400
Mold Shrinkage, in./in.		0.02–0.05	0.02–0.06	0.001–0.004	0.008–0.012
Extrusion Temp, F		325–400	350–385	—	<375
HEAT RESISTANCE					
Max Rec Svc Temp, F		150–220	140–220	150–165	170–212
Heat Dist Temp, F					
66 psi	D648	—	—	170–185	190–210
264 psi	D648	—	—	140–170	130–150
Softening Point, F		—	—	—	240–280
CHEMICAL RESISTANCE		Generally resistant to alkalis and weak acids. Moderately to not resistant to strong acids. Not resistant to ketones and esters; aromatic hydrocarbons produce swelling			Excellent to all acids and most common alkalis[c]
USES		Parts made by molding, high speed extrusion, calendering. Blown extruded film. Vacuum cleaner parts, handlebar grips, doll parts, hair curlers, safety goggle cups, grommets, toy tires, garden hose, and protective garments	Parts made by calendering, extrusion. Insulation and jacketing for: communication and low tension power wire and cable, building wiring, appliance and machine tool cords, and switchboard cable	Parts made by calendering, laminating, molding, extrusion. Fume hoods and ducts, storage tanks, chemical piping, plating tanks, phonograph records. Sheets and shapes for decorative panels, other building uses	Extrusions: gasket rods, valve seats, flexible chemical tubing and pipe, tape for wrapping joints, chemical conveyor belts. Moldings: spray-gun handles, acid dippers, parts for rayon producing equipment

[a]Where two values or ranges are given, they represent unoriented and oriented forms, respectively.
[b]Modulus of elasticity in compression. [c]Unaffected by aliphatic and aromatic hydrocarbons, alcohols, esters, etc.

Polyvinyl Alcohol, Butyral and Formal

Material →		Polyvinyl Alcohol	Polyvinyl Butyral	Polyvinyl Formal
PHYSICAL PROPERTIES	ASTM			
Specific Gravity	D792	1.21–1.31	1.07–1.20	1.2–1.4
Ther Cond, Btu/hr/sq ft/°F/ft	C177	0.46	—	0.089
Coef of Ther Exp, per °F	D696	3.88–6.65 x 10^{-5}	4.4–12.7 x 10^{-5}	3.55–4.27 x 10^{-5}
Refractive Index	D542	1.49–1.53	1.48–1.49	1.5
Specific Heat, Btu/lb/°F		0.3	0.4	—
Transmittance (luminous), %		[a]	85–91	80–90
Water Absorption (24 hr), %	D570	>30	1.0–3.0	0.5–3.0
Flammability	D635	Slow burning	Slow burning	Slow burning
MECHANICAL PROPERTIES				
Mod of Elast in Tension, psi	D638	—	3.5–4.0 x 10^5	5-7 x 10^5
Tensile Strength, 1000 psi	D638	1–5	4–8.5	9–11
Elongation (in 2 in.), %	D638	300–600	5–60	5–20
Hardness (Rockwell)	D785	—	L95	M85
Hardness (Shore A)		10–100	—	—
Impact Strength (Izod notched), ft-lb/in.	D256	—	0.74–1.02	0.8–20
Mod of Elast in Flex, psi		—	—	5–6 x 10^5
Flexural Strength, 1000 psi	D790	—	10	17–18
ELECTRICAL PROPERTIES				
Volume Resistivity, ohm-cm	D257	[b]	>10^{14}	—
Dielectric Strength (short time), v/mil	D149	[b]	400	300–600
Dielectric Constant				
60 Cycles	D150	[b]	3.61	3.7
10^6 Cycles	D150	[b]	3.33	3.0
Dissipation Factor				
60 Cycles	D150	[b]	0.0070	0.010
10^6 Cycles	D150	[b]	0.0065	0.023
FABRICATING PROPERTIES				
Compression Molding				
Pressure, 1000 psi		5–15	1–2	1–10
Temperature, F		250–300	320–400	275–325
Injection Molding				
Pressure		—	11–15	14–32
Temperature, F		—	400	325–425
Mold Shrinkage, in./in.		—	—	0.0015–0.0035
HEAT RESISTANCE				
Max Rec Svc Temp, F		—	115	130–165
Heat Dist Temp, F	D648	—	115–140	155–185
CHEMICAL RESISTANCE		Good resistance to organic solvents and petroleum. Attacked by strong acids. Softened or dissolved by weak acids and by alkalis	Resistant to alkalis, aliphatic hydrocarbons, and most oils. Attacked by acids, alcohols, esters and ketones. Butyral used with wider range of solvents than Formal	
USES		Adhesives and binders, textile sizing, coating and sizing for paper, thickening agents. Molded: chemical and oxygen tubing, gaskets and diaphragms. Film: airtight bags, packaging for chemicals	Plasticized form used as interlayer for safety glass. Solution uses: adhesive primer, metal conditioner, cloth waterproofing	Base for electrical insulating enamel with high heat resistance. Metal wire and cable coatings requiring high toughness and adhesion

[a] Transparent to opaque.
[b] Under atmospheric conditions enough water will be absorbed to make most electrical measurements useless.

High Pressure Laminates (General Purpose)

Grade →	CE (canvas-phenolic)	A (asbestos paper-phenolic)	AA (asbestos cloth-phenolic)	G-3 (glass cloth-phenolic)
PHYSICAL PROPERTIES				
Density, gm/cu cm	1.32	1.72	1.70	1.65
Ther Cond, Btu/sq ft/hr/°F/ft	0.17	—	—	—
Max Rec Svc Temp, F				
Short time	300	400	400	410
Continuous	250	275	275	290
Coef of Ther Exp, 10^{-5} per °F				
Lengthwise	0.58	0.31	0.58	0.52
Crosswise	0.68	0.49	0.58	0.62
Water Absorption (24 hr), %				
1/16 In. Thick	1.3	1.3	2.5	1.8
1/8 In. Thick	0.9	0.8	2.0	1.2
1/2 In. Thick	0.5	0.5	1.2	0.7
MECHANICAL PROPERTIES				
Ten Str, 1000 psi				
Lengthwise	11	10	12	23
Crosswise	9	8	10	20
Flex Str, 1000 psi				
Lengthwise	22	20	21	32
Crosswise	17	18	19	28
Compr Str (flatwise), 1000 psi	39	40	38	50
Mod of Elast in Flex, 10^5 psi				
Lengthwise	9	23	16	15
Crosswise	8	14	14	12
Impact Str (edgewise), ft lb/in.				
Lengthwise	1.6	1.0	4.5	7.5
Crosswise	1.4	0.9	4.0	6.0
Hardness (Rockwell)	M105	M111	M103	M120
Bond Strength, lb	2200	800	2000	1000
ELECTRICAL PROPERTIES				
Dielec Str (perp, short time), v/mil				
1/16 In. Thick	500	225	85	700
1/8 In. Thick	360	160	70	600
Dielec Str (par., step by step, 1/8 in. thick), kv				
Cond A	45	10	—	—
Cond D48/50	5	—	—	—
Dissip Factor (10^6 cycles)				
Cond A	0.055	—	—	0.030
Cond D 24/23	0.070	—	—	—
Dielec Const (10^6 cycles, cond A)	5.3	—	—	6.5
Insulation Res (cond C96/35/90), meg	—	—	—	200
Arc Resistance, sec	10	10	10	10
AIEE Insulation Class	A	B	B	B
USES	Switchboard panels, circuit breaker and switch arms, terminal blocks, electrode supports for plating tanks, bases for motors, bobbin heads (often in combination with XX)	Mechanical parts in drying ovens, tenter rails	Rotor vanes, water pumping thrust washers, armature slot wedges, caustic resistant applications, electric appliance insulation	Armature slot wedges, structural parts requiring good electrical properties, electrical equipment operating at relatively high temperatures

High Pressure Laminates (General Purpose)—concluded

Grade →	G-5 (glass cloth–melamine)	G-10 (glass cloth–epoxy)	GPO-1 (glass mat–polyester)	Commercial and Trunk Fibre
PHYSICAL PROPERTIES				
Density, gm/cu cm	1.9	1.78	1.5–1.9	1.15
Ther Cond, Btu/sq ft/hr/°F/ft	0.29	—	—	—
Max Rec Svc Temp, F				
Short time	425	350	350	—
Continuous	300	250	250	—
Coef of Ther Exp, 10^{-5} per °F				
Lengthwise	0.31	—	1.1	—
Crosswise	0.34	—	—	—
Water Abs (24 hr), %				
1/16 In. Thick	1.0	0.09	1.0	66
1/8 In. Thick	0.6	0.06	0.70	61
1/2 In. Thick	0.4	0.03	0.35	36
MECHANICAL PROPERTIES				
Ten Str, 1000 psi				
Lengthwise	37	—	12	7.5
Crosswise	30	—	10	5.5
Flex Str, 1000 psi				
Lengthwise	65	72	23	14
Crosswise	50	63	20	12
Compr Str (flatwise), 1000 psi	70	—	40	20
Mod of Elast in Flex, 10^5 psi				
Lengthwise	17	—	15	—
Crosswise	15	—	13	—
Impact Str (edgewise), ft lb/in.				
Lengthwise	12.0	14.4	12	3.5
Crosswise	9.0	10.6	10	2.9
Hardness (Rockwell)	M120	—	M100	R50
Bond Strength, lb	1700	2500	1000	1000
ELECTRICAL PROPERTIES				
Dielec Str (perp, short time), v/mil				
1/16 In. Thick	350	810	650	175
1/8 In. Thick	260	570	500	150
Dielec Str (par., step by step, 1/8 in. thick), kv				
Cond A	32	55	60	—
Cond D48/50	12	60	33	—
Dissip Factor (10^6 cycles)				
Cond A	0.016	0.0119	0.03	0.024
Cond D 24/23	0.030	0.0126	0.06	0.030
Dielec Const (10^6 cycles, cond A)	6.8	4.8	4.3	—
Insulation Res (cond C96/35/90), meg	100	1×10^5	—	—
Arc Resistance, sec	200	17	100	100
AIEE Insulation Class	B	B	B	—
USES	Switchboard panels, arc barriers and circuit breaker parts, armature and slot wedges, structural parts, electrical applications requiring high strength and arc resistance, high temperature applications	Printed circuits; other applications where high insulation resistance and dimensional stability, are required.	Panel boards, slot wedges, spacers, coil blocking, layer insulation, core corner protectors, terminal plates, structural applications	Washers, terminal block covers, insulating plates and switch covers, arch supporters, bobbin and coil spool heads, arc barriers, shoe fiber, switch and appliance insulation, knee pads, golf club head plates, deep formed parts, trunks, cases, wastebaskets, mill boxes

High Pressure Laminates (Mechanical)

Grade →	X (kraft paper–phenolic)	P (paper–plasticized phenolic)	PC (paper–phenolic)	ES 1, 2, 3 (paper base)[a]
PHYSICAL PROPERTIES				
Density, gm/cu cm	1.35	1.33	1.34	—
Ther Cond, Btu/hr/sq ft/°F/ft	0.17	0.17	0.17	—
Max Rec Svc Temp, F				
Short Time	275	275	250	—
Continuous	225	250	200	—
Coef of Ther Exp, 10^{-5} per °F				
Lengthwise	0.61	0.43	—	—
Crosswise	0.77	0.68	—	—
Water Absorption (24 hr), %				
1/16 In. Thick	4.0	2.2	3.2	2.5
1/8 In. Thick	2.3	1.5	2.0	1.8
1/2 In. Thick	0.9	—	—	—
MECHANICAL PROPERTIES				
Ten Str, 1000 psi				
Lengthwise	20	12	10.5	12–15
Crosswise	16	9	8.5	8–12
Flex Str, 1000 psi				
Lengthwise	28	15	14	15
Crosswise	23	13	11	15
Compr Str (flatwise), 1000 psi	36	25	22	—
Mod of Elast in Flex, 10^5 psi				
Lengthwise	18	12	10	—
Crosswise	13	9	8	—
Impact Str (edgewise), ft lb/in.				
Lengthwise	0.9	0.8	0.9	0.25
Crosswise	0.7	0.6	0.8	0.22
Hardness (Rockwell)	M110	M95	M75	M118
Bond Strength, lb	900	—	—	—
ELECTRICAL PROPERTIES				
Dielec Str (perp, short time), v/mil				
1/16 In. Thick	700	650	600	—
1/8 In. Thick	500	470	425	—
Dielec Str (par., step by step, 1/8 in. thick), kv				
Cond A	—	50	—	—
Cond D48/50	—	10	—	—
Dissip Factor (10^6 cycles)				
Cond A	—	—	—	—
Cond D 24/23	—	—	—	—
Dielec Const (10^6 cycles, cond A)	—	—	—	—
Insulation Res (cond C96/35/90), meg	—	—	—	—
Arc Resistance, sec	10	—	—	—
AIEE Insulation Class	A	A	A	A
USES	Structural parts for radio, aircraft and electrical equipment and switchgear. Terminal boards or panels, insulating washers, bushings, coil forms, brushholder bushings	Insulating washers, terminal boards, plug and socket bases, switch bases and panels for subassemblies	Motor and generator terminal boards, insulating washers, terminal strips, switch bases and panels, staked terminal boards and strips	Engraved nameplates, signs

[a]ES-1 is melamine laminate; ES-2 is phenolic laminate; ES-3 has phenolic core, melamine base.

High Pressure Laminates (Mechanical)—concluded

Grade →	C (cotton canvas–phenolic)	L (cotton linen–phenolic)	MC (cotton fabric–melamine)	Bone Fibre
PHYSICAL PROPERTIES				
Density, gm/cu cm	1.35	1.34	1.5	1.3
Ther Cond, Btu/hr/sq ft/°F/ft	0.17	0.17	0.17	0.17
Max Rec Svc Temp, F				
Short Time	275	275	275	—
Continuous	225	225	225	221
Coef of Ther Exp, 10^{-5} per °F				
Lengthwise	0.58	0.43	—	—
Crosswise	0.68	0.58	—	—
Water Absorption (24 hr), %				
1/16 In. Thick	4.4	2.0	2.2	55
1/8 In. Thick	2.5	1.4	1.6	48
1/2 In. Thick	1.2	0.8	1.0	25
MECHANICAL PROPERTIES				
Ten Str, 1000 psi				
Lengthwise	11	14	11	8
Crosswise	9	10	7	6
Flex Str, 1000 psi				
Lengthwise	22	23	23	15
Crosswise	18	18	18	13
Compr Str (flatwise), 1000 psi	37	35	45	30
Mod of Elast in Flex, 10^5 psi				
Lengthwise	10	11	—	12
Crosswise	9	8	—	8
Impact Str (edgewise), ft lb/in.				
Lengthwise	2.3	1.3	0.9	3.0
Crosswise	2.2	1.2	0.9	2.4
Hardness (Rockwell)	M103	M105	M115	R80
Bond Strength, lb	2000	1700	1900	—
ELECTRICAL PROPERTIES				
Dielec Str (perp, short time), v/mil				
1/16 In. Thick	500	500	—	175
1/8 In. Thick	360	360	—	150
Dielec Str (par., step by step, 1/8 In. thick) kv				
Cond A	15	15	—	—
Cond D 48/50	—	—	—	—
Dissip Factor (10^6 cycles)				
Cond A	—	0.055	—	—
Cond D 24/23	—	0.070	—	—
Dielec Const (10^6 cycles, cond A)	6.0	5.8	—	—
Insulation Res (cond C96/35/90), meg	—	—	—	—
Arc Resistance, sec	10	10	100	100
AIEE Insulation Class	A	A	—	—
USES	Gears and pinions, cams, pulleys, bobbin heads, chemical piping and fittings, bearings	Small gears and pinions, parts requiring intricate machining, breaker arms, fairleads and knobs	Plating barrel applications; others requiring good resistance to caustics	Gears, cams, fairleads, bushings, grommets, switch handles, terminal blocks, armature slot wedges, threaded and tapped pieces, sugar tips

High Pressure Laminates (Electrical)

Grade →	XX (paper-phenolic)	XXP (paper-phenolic)	XXX (paper-phenolic)	XXXP (paper-plasticized phenolic)	LE (cotton linen-phenolic)
PHYSICAL PROPERTIES					
Density, gm/cu cm	1.34	1.32	1.32	1.32	1.32
Ther Cond, Btu/sq ft/hr/°F/ft	0.17	0.17	0.17	0.17	0.17
Max Rec Svc Temp, F					
Short Time	300	275	300	275	300
Continuous	250	250	250	250	250
Coef of Ther Exp, 10^{-5} per °F					
Lengthwise	0.41	0.58	0.41	0.58	0.58
Crosswise	0.74	0.92	0.71	0.92	0.80
Water Absorption, (24 hr), %					
1/16 In. Thick	1.3	1.3	0.8	0.40	1.3
1/8 In. Thick	0.9	0.9	0.5	—	0.8
1/2 In. Thick	0.5	—	0.3	—	0.5
MECHANICAL PROPERTIES					
Ten Str, 1000 psi					
Lengthwise	16	11	15	12	13.5
Crosswise	13	8.5	12	9.5	9.5
Flex Str, 1000 psi					
Lengthwise	18	18	18	21	18
Crosswise	14	14	14	15	15
Compr Str (flatwise), 1000 psi	34	25	32	25	37
Mod of Elast in Flex, 10^5 psi					
Lengthwise	14	9	13	11	10
Crosswise	11	7	10	8	8
Impact Str (edgewise), ft-lb/in.					
Lengthwise	0.55	0.55	0.5	0.6	1.3
Crosswise	0.50	0.50	0.45	0.5	1.2
Hardness (Rockwell)	M105	M100	M110	M112	M105
Bond Strength, lb	1100	—	1200	—	1800
ELECTRICAL PROPERTIES					
Dielec Str (perp, short time), v/mil					
1/16 In. Thick	700	700	650	650	500
1/8 In. Thick	500	500	470	470	360
Dielec Str (par., step by step, 1/8 in. thick), kv					
Cond A	50	65	65	65	50
Cond D48/50	10	15	15	33	6
Dissip Factor (10^6 cycles)					
Cond A	0.040	0.037	0.034	0.030	0.048
Cond D 24/23	0.046	0.045	0.038	0.035	0.058
Dielec Const (10^6 cycles, cond A)	5.3	4.5	4.7	4.27	5.3
Insulation Res. (cond C96/35/90), megohms	60	500	1000	20,000	30
Arc Resistance, sec	10	10	10	10	10
AIEE Insulation Class	A	A	A	A	A
USES	Panels for switchboards and instruments, switch and circuit breaker arms, terminal blocks for motors and transformers, coil forms for radio and television, brush holder bushings, bobbin heads and spools	Condenser stator brackets, wave change switch rotors and stators, plug and socket bases, terminal boards and subpanels, insulating washers	Panels for radio and television equipment; jack spacers, radio coil forms, high voltage switchgear	Condenser stator brackets, wavechange switch rotors and stators, terminal boards and subpanels, coil support bases	Terminal blocks and strips, panels, high humidity applications

High Pressure Laminates (Electrical)—concluded

Grade →	G-2 (glass cloth–phenolic)	G-6 (glass cloth–silicone)	G-7 (glass cloth–silicone)	N-1 (nylon fabric–phenolic)	Electrical Insulation Fibre
PHYSICAL PROPERTIES					
Density, gm/cu cm	—	1.65	1.68	1.15	1.15
Ther Cond, Btu/sq ft/hr/°F/ft	—	0.17	0.17	—	—
Max Rec Svc Temp, F					
Short Time	410	500	500	200	—
Continuous	290	400	400	165	—
Coef of Ther Exp, 10^{-5} per °F					
Lengthwise	—	0.31	—	—	—
Crosswise	—	0.31	—	—	—
Water Absorption (24 hr), %					
1/16 In. Thick	1.50	0.3	0.3	0.3	66
1/8 In. Thick	0.95	0.25	0.20	0.2	61
1/2 In. Thick	0.55	0.15	0.15	0.1	36
MECHANICAL PROPERTIES					
Ten Str, 1000 psi					
Lengthwise	500	250	400	600	175
Crosswise	425	185	350	450	175
Flex Str, 1000 psi					
Lengthwise	30	50	55	62	—
Crosswise	10	45	30	55	—
Compr Str (flatwise), 1000 psi					
Mod of Elast in Flex, 10^5 psi					
Lengthwise	0.025	0.0022	0.0015	0.024	—
Crosswise	0.080	0.0227	0.0150	0.030	—
Impact Str (Edgewise), ft-lb/in. notch					
Lengthwise	5.5	4.18	3.9	3.3	—
Crosswise	5000	4000	2500	5×10^4	—
Hardness (Rockwell)	—	M220	M220	—	M100
Bond Strength, lb	B	H	H	A	A
ELECTRICAL PROPERTIES					
Dielec Str (perp, short time), v/mil					
1/16 In. Thick	16	13	23	8.5	7.5
1/8 In. Thick	11	10	18	8	5.5
Dielec Str (par., step by step, 1/8 in. thick), kv	30	23	44	18	—
Cond A	20	19	37	15	—
Cond D48/50	38	40	45	—	32
Dissip Factor (10^6 cycles)					
Cond A	13	—	14	6	—
Cond D 24/23	10	—	12	5	—
Dielec Const (10^6 cycles, cond A)	6.6	15.1	12.1	3.7	—
Insulation Res (cond C96/35/90), meg	4.7	9.5	9.6	3.3	—
Arc Resistance, sec	110	95	100	105	—
AIEE Insulation Class	1400	1000	800	1200	—
USES	Class B insulation; other applications where good temperature resistance is required but mechanical properties are not critical	Insulation applications where high temperature resistance, arc resistance and low losses are needed, such as Class H transformers	Radio transmitter parts; Class H transformers; low loss, high frequency radio and radar insulators; motor slot wedges; slot liners; top sticks	High voltage applications; radio wave change switch stators and rotors, where low losses are critical; electrical insulating parts that must be postformed	Armature slot insulation, armature end laminations, field coil insulation, metal box liners, washers, arc shields, formed slot wedges, gaskets, specialties

Rubber

Type ➡	Natural Rubber	Butadiene-Styrene (GR-S)	Butadiene-Acrylonitrile (nitrile)	Chloroprene (neoprene)	Butyl (isobutylene-isoprene)
PHYSICAL PROPERTIES					
Spec Grav	0.93	0.94	1.00	1.25	0.90
Ther Cond, Btu/hr/sq ft/°F/ft	0.082	0.143	0.143	0.112	0.053
Electrical Insulation	Good	Good	Poor	Fair	Good
Flame Resistance	Poor	Poor	Poor	Good	Poor
MECHANICAL PROPERTIES					
Ten Str, psi					
Pure Gum	2500–3500	200–300	500–900	3000–4000	2500–3000
Black	3500–4500	2500–3500	3000–4500	3000–4000	2500–3000
Elongation, %					
Pure Gum	750–850	400–600	450–700	800–900	750–950
Black	550–650	500–600	450–650	500–600	650–850
Hardness (durometer)	A30–A90	A40–A90	A40–A95	A40–A95	A40–A75
Rec Min Svc Temp, F	–60	–60	0	–40	0
Rec Max Svc Temp, F	180	180	250	240	210
Coef of Ther Exp (cubical), 10^{-5} per °F	37	37	39	34	32
Rebound					
Cold	Excellent	Good	Good	Very good	Bad
Hot	Excellent	Good	Good	Very good	Very good
Tear Resistance	Excellent	Fair	Good	Fair to good	Good
Abrasion Resistance	Excellent	Good to excellent	Good	Good	Fair
CHEMICAL RESISTANCE					
Sunlight Aging	Poor	Poor	Poor	Very good	Very good
Oxidation	Good	Good	Good	Excellent	Very good
Heat Aging	Good	Very good	Excellent	Excellent	Excellent
Solvents					
Aliphatic Hydrocarbons	Poor	Poor	Excellent	Good	Poor
Aromatic Hydrocarbons	Poor	Poor	Good	Fair	Poor
Oxygenated, Alcohols	Good	Good	Poor	Poor	Good
Oil, Gasoline	Poor	Poor	Excellent	Good	Poor
Animal, Vegetable Oils	Poor to good	Poor to good	Excellent	Good	Excellent
Acids					
Dilute	Fair to good	Fair to good	Good	Excellent	Excellent
Concentrated	Fair to good	Fair to good	Good	Good	Excellent
Permeability to Gases	Fair	Fair	Fair	Low	Very low
Water Swell Resistance	Fair	Excellent	Excellent	Fair	Excellent
USES	Pneumatic tires and tubes; power transmission belts and conveyor belts; gaskets; mountings; hose; chemical tank linings; printing press platens; sound or shock absorption; seals against air, moisture, sound and dirt		Carburetor diaphragms, self-sealing fuel tanks, aircraft hose, gaskets, gasoline and oil hose, cables, machinery mountings, printing rolls	Flexible petroleum tubes and hoses, petroleum and chemical tank linings; electrical insulation in contact with oil, flashlight cases, electrical sockets, special truck tires	Truck and automobile tire inner tubes, airing bags for tire vulcanization and molding, steam hose and diaphragms, flexible electrical insulation

Rubber—concluded

Type →	Polysulfide (Thiokol)	Silicone (polysiloxane)	Urethane (diisocyanate polyester)	Fluorinated Acrylic (dihydroperfluoro-butylacrylate)
PHYSICAL PROPERTIES				
Spec Grav	1.35	1.25	1.25	1.5
Ther Cond, Btu/hr/sq ft/°F/ft	—	67	—	—
Electrical Insulation	Fair	Good	Good	Good
Flame Resistance	Poor	Fair	Good	Good
MECHANICAL PROPERTIES				
Ten Str, psi				
Pure Gum	>1000	600–1000	>5000	1200
Black	—	—	—	—
Elongation, %				
Pure Gum	450–650	60–400	540–750	300
Black	—	—	—	300
Hardness (durometer)	A40–A85	A40–A85	A35–A100	A55
Min Rec Svc Temp, F	−60	−120	−65	0
Max Rec Svc Temp, F	+250	+550	+240	+450
Coef of Ther Exp (cubical), 10^{-5} per °F	—	67	—	—
Rebound				
Cold	Good	Excellent	Bad	—
Hot	Good	Excellent	Good	—
Tear Resistance	Poor	Poor	Good	Poor
Abrasion Resistance	Poor	Poor	Excellent	Poor
CHEMICAL RESISTANCE				
Sunlight Aging	Very good	Excellent	Excellent[a]	Good
Oxidation	Very good	Very good	Very good	Good
Heat Aging	Fair	Outstanding	Excellent[a]	Good
Solvents				
Aliphatic Hydrocarbons	Excellent	Poor	Excellent	Excellent
Aromatic Hydrocarbons	Excellent	Poor	Excellent[b]	Excellent
Oxygenated, Alcohols	Very good	Fair	Poor	Good
Oil, Gasoline	Excellent	Fair	Excellent	Excellent
Animal, Vegetable Oils	Excellent	Excellent	Excellent	Excellent
Acids				
Dilute	Good	Excellent	Fair	Excellent[c]
Concentrated	Good	Fair	Poor	Excellent[d]
Permeability to Gases	Extremely low	Fair	Excellent	Fair
Water Swell Resistance	Excellent	Excellent	Excellent	Poor
USES	Seals, gaskets, diaphragms, valve seat disks, flexible mountings, hose in contact with solvents, balloons, boats, life vests and rafts	Wire and cable covering, gaskets, tubing, diaphragms, vibration mountings, rollers, insulators, valve seats and closures	Fork lift truck wheels, airplane tail wheels, back-up wheels for turbine blade grinders, spinning cots for glass fiber, hydraulic accumulators, shoe heels	O-rings; V-rings; diaphragms; special applications involving contact with halogenated solvents, organic phosphates and carbon tetrachloride

[a] Discolors, but no change in properties.
[b] For up to 80% aromatics.
[c] To diesters, 450 F.
[d] To fire resistant hydraulic fluids, 450 F.

Hard Rubber

Type →	Molded Parts[a]								
	GP	GP	GP	GP	H Ht	H Ar	Ar Ht Wr, H DQ	H Ht, Ch	Ht Ma
PHYSICAL PROPERTIES[b]									
Spec Grav	1.21	1.21	1.28	1.54	1.65	1.95	1.71	1.24	1.80
Water Abs (24 hr), %	0.08	0.06	0.14	0.30	0.06	0.06	0.10	0.12	0.04
Color	Black	Black	Black	Black	Red-brown	Red-brown	Red-brown	Black	Black
MECHANICAL PROPERTIES									
Ten Str, 1000 psi	8.3	7.9	4.5	2	6.75	4	5.8	7.17	5.4
Elong (in 2 in.), %	4.00	4.00	3.40	2.00	2.60	1.00	2.60	2.70	1.80
Hardness (Rockwell)	B108–76	B107–91	B129–79	B103–27	B83–60	B65–41	B82–55	B115–85	B82–54
Hardness (durometer)	81–87	81–87	78–84	76–82	85–92	87–95	86–92	84–90	84–92
Impact Str (Izod notched), ft-lb/in.	0.48	0.45	0.45	0.27	0.35	0.32	0.38	0.41	0.34
Flex Str, 1000 psi	12.5	11.3	7.1	2.8	8.7	8.4	9.1	11.3	10
Heat Dist Temp, F	142	145	134	Low	283	300	246	275	295
ELECTRICAL PROPERTIES									
Dielec Str (60 Cycles), v/mil	435	496	344	377	393	600	371	400	420
Dielec Const[c]	3.00	2.95	3.80	4.95	4.10	4.80	4.60	3.50	4.10
Dissip Factor[c]	0.8	0.7	1.2	2.8	1.2	2.5	1.2	1.6	1.8
Surface Res (74 F, 86% RH), meg	4.8×10^5	$>10^8$	$>10^8$	5.08×10^5	5.32×10^5	—	4.46×10^4	2.0×10^3	8.02×10^4

Type →	Sheets[a]					Rods and Tubes[a]			
	GP	El[d]	H Ht	H Ht, Ch	St Fl, H DQ	GP	El	H Ht, Ch	St Fl, H DQ
PHYSICAL PROPERTIES[b]									
Spec Grav	1.20	1.17	1.43	1.24	1.27	1.21	1.15	1.24	1.27
Water Abs (24 hr), %	0.06	0.22	0.15	0.12	0.08	0.06	0.12	0.12	0.07
Color	Black	Black	Black	Black	Yellow-brown	Black	Black	Black	Yellow brown
MECHANICAL PROPERTIES									
Ten Str, 1000 psi	9.3	2.55	7.4	7.17	7.45	9.7	3.6	7.17	6.5
Elong (in 2 in.), %	5.00	33.00	1.20	2.70	5.30	5.00	16.00	2.70	3.80
Hardness (Rockwell)	112–79	—	86–60	115–85	112–80	107–70	—	115–85	112–80
Hardness (durometer)	80–86	50–60	86–92	84–90	80–86	80–86	65–75	84–90	80–86
Impact Str (Izod notched), ft-lb/in.	0.48	0.51	0.53	0.41	0.50	0.48	0.48	0.41	0.52
Flex Str, 1000 psi	16.6	—	9.64	11.3	14.95	11.375	—	11.3	9.06
Heat Dist Temp, F	159	Low	221	275	150	163	Low	275	217
ELECTRICAL PROPERTIES									
Dielec Str (60 Cycles), v/mil	487	437	613	400	415	524	512	400	374
Dielec Const[c]	2.95	3.00	3.25	3.50	3.70	2.90	3.15	3.50	3.60
Dissip Factor[c]	0.5	1.3	0.6	1.6	0.6	0.5	1.4	1.6	0.9
Surface Res (74 F, 86% RH), meg	2.23×10^7	2.66×10^4	$> 10^8$	2.0×10^3	7.98×10^4	$> 10^8$	$> 10^8$	2.0×10^3	6.73×10^4

[a]GP = general purpose, H = high, HT = heat resistance, Ar = arc resistance, Wr = wear resistance, DQ = dielectric quality, Ch = chemical resistance, MA = low moisture absorption, El = elongation, St = strength, Fl = flow resistance. These designations are arbitrary abbreviations of principal properties and are not standard.
[b]Hard rubber in general has a thermal coefficient of linear expansion of 0.00004 per °F.
[c]Frequency: 1 kc-1 mc.
[d]Semihard.

Flexible Foams

LATEX

Density, lb/cu ft	6.0–7.0
Ther Cond, Btu/hr/sq ft/°F/ft	0.021–0.025
Tensile Strength, psi	10–20
Max Rec Svc Temp, F	160
Flammability	Burns
Tear Strength, lb/in.	1.2
Resilience, %	64
Rebound, in.	2.5
Elongation, %	380
Compression Loss, %	
50,000 Flexes	13.0
300,000 Flexes	15.0
Compression Set, %	
22 hr at 158 F	4.6
22 hr at 177 F	4.1
Hysteresis Loss, %	23.2
RMA Compression, lb	30.0

POLYETHYLENE (Cellular)[a]

Tensile Strength	670
Elongation, %	310
Specific Gravity	0.47
Dielectric Strength, v/mil	
Short Time	220
Long Time	190
Dissipation Factor	
1000 Cycles	0.00033
10,000 Cycles	0.00038
Dielectric Constant	
1000 Cycles	1.48
10,000 Cycles	1.49

[a]Wire insulation for No. 14 AWG (0.250-in. o. d.). Wire insulation is the primary use of cellular polyethylene at present.

VINYL (Open Cell)

Density, lb/cu ft	4 and up
Heat Sealability	Excellent
Tensile Strength, psi	10–200
Elongation, %	75–300
Flammability	Self-extinguishing
Indentation Load	
Deflection (25% def)	
Original, lb/50 sq in.	3–500
After Aging, % chg[a]	±20
Compression Set (max, 2 hr at 158 F), %	15
Set after Dynamic Flexing (max, 250,000 cycles), %	10
Chemical Resistance[b]	
Strong Acids	E
Strong Alkalis	E
Grease, Oils	G
Organic Solvents	P to E
Water	E
High Humidity	E
Sunlight	G

[a]Air oven aging 22 hr, 212 F.
[b]E = excellent; G = good; P = poor.

SYNTHETIC RUBBERS

Type →	Neoprene	Butadiene-Styrene (GR-S)	Butadiene-Acrylonitrile
Density, lb/cu ft	10–30	4.5	10–25
Ther Cond, Btu/hr/sq ft/°F/ft	0.021–0.029	0.018	0.021–0.025
Tensile Strength, psi	20–100	80	40
Max Rec Svc Temp, F	180	160	210

URETHANES

Density[a] →	1	2-4	6-8	10-12	16-20
Yld Str (0.2% offset), psi	2.5	4–20	50–75	200	—
Compr Str (50% defl), psi	5	9–48	78–150	200–380	—
Coef of Ther Exp (−22 to 86 F)					
10^{-5} per °F	—	1.4	—	—	5
Ther Insulation Coef (K)	0.20	0.20–0.21	0.22–0.23	0.26	0.28–0.30
Water Absorption, lb/cu ft.					
25-day soak	28	22.8–24	—	—	2–4
120 hr at 50% RH	0.005	0.006–0.027	—	—	0.067–0.084
120 hr at 98% RH	0.38	0.38–0.39	—	—	0.359–0.560
Dielec Const (10^3) Cycles	—	2.2–2.3	—	2.5	2.70–2.85
Vol Res, 10^{14} ohm-cm	—	6.8–6.9	—	7.2	7.7–8.3
Sound Absorption Coef					
250 Cycles	—	0.73	0.20	0.22	—
500 Cycles	—	0.33	0.22	0.21	—
1000 Cycles	—	0.37	0.20	0.31	—
Bond Str, psi					
Aluminum	6	10–27	—	56	158
Glass	5	9–25	—	50	142
Steel	7	12–29	—	62	146
Wood	8	17–29	—	62	170
Flame Res.[b]					
2 Lb/Cu Ft	Incombustible				
10 Lb/Cu Ft	Self-extinguishing				
Max Rec Svc Temp, F	200				
Heat Dist Temp (5 psi flex, 0.10 in. defl), F	130				
Chemical Resistance	Swell slightly in many chemical solutions. Attacked by strong acids and alkalis				

[a]Density in lb per cu ft.
[b]Federal Bldg Spec SSA118A.

Foamed-in-Place Foams

EPOXIES, PHENOLICS AND URETHANES

Type and Density[a] →	Epoxy		Phenolic		Urethane			
	25-28	39	2-5	7-10	0.5-5	6-9	12-15	18-25
Compr Str, psi	1000	—	9–31	45–130	5–30	150–225	350–600	800–1200
Ten Str, psi	900	—	4–35	35-75	10–50	150–250	305–400	450–1000
Flex Str, psi	—	4200	24–40	75–230	—	—	—	—
Shear Str, psi	—	—	8–30	40–135	2–50	50–120	180–250	>250
Ther Cond, Btu/hr/sq ft/°F/ft	—	0.067	0.020	0.023	0.02–0.03	0.02–0.03	0.02–0.03	0.02–0.03
Coef of Ther Exp, 10^{-5}, per °F	4.0	1.05	—	—	1.5	2.9	4.4	—
Mod of Elast in Tension, psi	60,000	—	—	—	—	—	—	—
Water Abs (vol), %	—	0.1	—	—	—	1.6	0.6	0.2
Water Abs (wt), %								
100% RH	—	—	13–51	10–51	—	—	—	—
50% RH	—	—	1–4	1–5	—	—	—	—
20% RH	—	—	½–1	1–2	—	—	—	—
Max Rec Svc Temp, F	—	—	300[b]	300[b]	250	250	250	300
Flammability	—	—	Nonflammable		Self-extinguishing			
Impact Str (unnotched), in.-lb	—	—	—	—	—	—	—	—
Dissip Factor	0.01–0.03	0.015	—	—	0.0005	0.001	0.002	0.003
Vol Res, ohm-cm	—	10^{13}	—	—	—	—	—	—
Dielec Str, v/mil	—	300	—	—	—	—	—	—
Dielec Const	2.0–6.0	1.9	—	—	1.05	1.15	1.25	1.40

[a]Density in lb per cu ft. [b]For intermittent exposure: 550 F.

SILICONES

Density[a] →	12[b]	14[b]
Compr Str (orig), psi	100	200
Compr Str (after aging), psi[c]		
77 F, 200 hr	100	190
500 F, ½ hr	5	25
500 F, 200 hr	20	45
Weight Loss During Expansion, %	1.2	1.3
Weight Loss After Heating, %		
1000 hr, 500 F	2.5	2.6
1000 hr, 570 F	8.0	4.2
72 hr, 700 F	8.5	5.2
Water Abs (24 hr), %	3.2	2.3
Heat Dist Temp, F	>700	>700
Flammability	No burn	No burn
Dielec Const (10^5 cycles)	1.23	1.25
Dissip Factor (10^5 cycles)	0.0004	0.00102
Ther Cond, Btu/hr/sq ft/°F/ft	0.025	0.025

[a]Density in lb per cu ft.
[b]Expanded at 320 F.
[c]Tested at 500 F.

POLYSTYRENES

Density[a] →	2	3	4	6	8	10
Ten Str, psi	30–50	55–75	65–85	90–110	110–120	120–130
Compr Str (5% offset), psi	15–20	25–35	40–50	60–70	70–80	90–100
Flex Str, psi	Flexible	60–90	90–120	130–160	200–230	280–310
Impact Str (unnotched), in.-lb/in.[b]	2.0–2.5	2.3–2.8	2.5–3.0	3.0–3.5	4.3–4.8	5.0–5.5
Ther Cond, Btu/hr/sq ft/°F/ft	0.0183	0.0188	0.0192	0.0203	0.0215	0.0225
Max Rec Svc Temp, F	185	185	185	185	185	185

Density 2-10[a]		Density 4-6[a]	
Dissip Factor	>0.0005	Dielec Const (73 F, 50% RH)	
Loss Factor	>0.0006	60 Cycles	1.19
Vol Res, 10^7 megohm-cm	>3.81	10^6 Cycles	1.02
Surface Res, 10^6 megohms	>9.8	Dielec Const (48 hr, 122 F)	
Dielec Str, v/mil		60 Cycles	1.24
Short time	48	10^6 Cycles	1.05
Step by Step	49	Dielec Const (96 hr, 95 F, 96% RH)	
		60 Cycles	1.24
		10^6 Cycles	1.05

[a]Density in lb per in. ft.
[b]1-in. wide specimen.

Prefoamed Foams

POLYSTYRENES AND CELLULOSE ACETATE

Type and Density[a] →	Polystyrene				Cellulose Acetate (cellular)		
	1.3	1.6	2.0	3.0-4.2	4	6-7	7-8
Compr Yld Str, psi	10–20	15–25	25–35	50–140	128	197	235
Ten Str, psi	30–45	50–70	80–100	105–185	112	158	183
Shear Str, psi	15–25	25–35	35–45	55–95	100	140	185
Flex Str, psi	>32	—	—	<170	73	147	177
Compr Mod, 1000 psi	0.45–1.1	0.75–1.35	1.15–1.75	1.7–5.3	5.5	7.0	13.5
Bending Mod, 1000 psi	0.20–0.75	0.65–1.2	1.2–1.9	—	3.5	5.5	—
Impact Str, psi	0.5–1.2	1.1–1.8	2.1–2.7	—	—	0.01	1.15
Flammability, ipm	Self-extinguishing types available				8.5	4.9	4.2
Ther Cond, Btu/hr/sq ft/°F/ft	0.020–0.024				0.025	0.026	0.027
Coef of Ther Exp, per °F	$2–5 \times 10^{-5}$				$2.0–2.5 \times 10^{-5}$		
Spec Ht, Btu/lb/°F	0.27				—		
Max Rec Svc Temp, F	155–165				200–350		
Water Abs (vol), %	<6				0.15, 1.05[b]		
Water Vapor Trans	1.5–3.0				—		
Dielec Const	<1.07				1.10–1.12		
Dissip Factor	<0.0004				0.002–0.003		

[a]Density in lb per cu ft. [b]Absorption in lb per cu ft at 50 and 100% RH, respectively.

UREA

Density, lb/cu ft	0.8–1.2
Compr Yld Str, psi	200
Ther Cond, Btu/hr/sq ft/°F/ft	0.015–0.018
Max Rec Svc Temp, F	200

SILICONE

Density, lb/cu ft	16[a]
Ther Cond, Btu/hr/sq ft/°F/ft	0.025
Water Abs (vol), %	2.1
Dielec Const	1.26
Dissip Factor	0.00105
Flammability	Nonflammable
Heat Dist Temp F	>700
Compr Str (orig), psi	325
Compr Str (after aging), psi[b]	
77 F, 200 hr	210
500 F, ½ hr	70
500 F, 200 hr	80
Weight Loss During Expansion, %	1.0
Weight Loss After Heating, %	
1000 hr, 500 F	2.6
1000 hr, 570 F	4.2
72 hr, 700 F	5.2

[a]Expanded at 320 F.
[b]Tested at 500 F.

EPOXIES AND MIXED COPOLYMER

Type and Density[a] →	Expanded Mixed Copolymer[b]	Epoxy			
		3	10	25	38
Compr Yld Str, psi	45–90	65	340	1200	6000
Ten Str, psi	120–350	55	320	1100	—
Flex Str, psi	—	—	—	—	4500
Compr Mod, 1000 psi	—	—	11	52	—
Bending Mod, 1000 psi	11.6	—	—	—	—
Ther Cond, Btu/hr/sq ft/°F/ft	0.022–0.029	0.014	0.020	—	0.054
Coef of Ther Exp, 10^{-5} per °F	3.4–4.0	—	2.2	—	1.6
Max Rec Svc Temp, F	—	300	300	300	350
Water Abs (Vol), %	0.05–0.10	1.3	0.25	0.1	0.09
Dielec Const	1.14–1.18	1.04	1.18	1.47	1.9
Dissip Factor	0.14–0.18	<0.0001	0.0004	0.003	0.009

[a]Density in lb per cu ft.
[b]Styrene-acrylonitrile resin and butadiene-acrylonitrile rubber.

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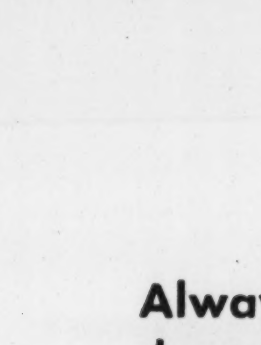

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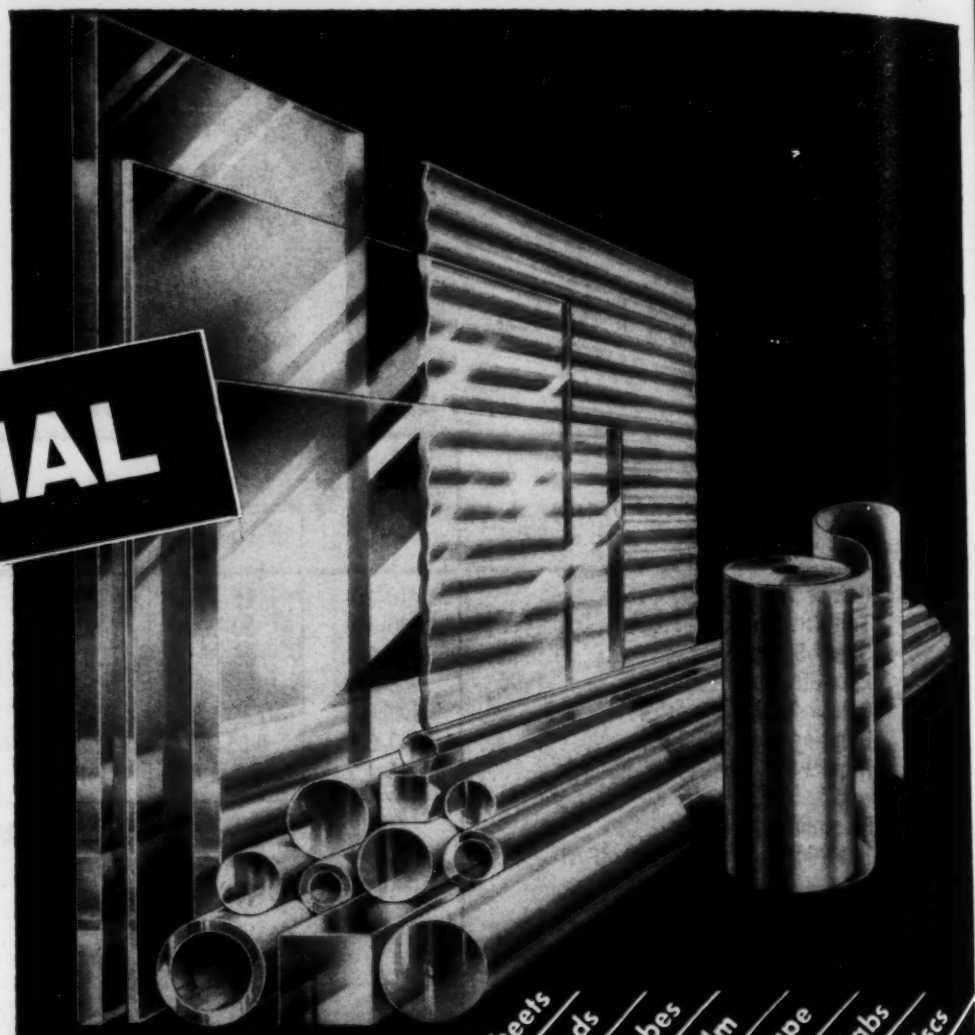

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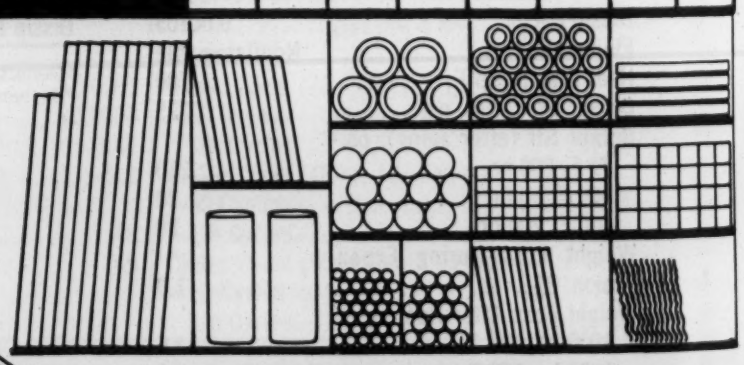

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DATA
SECTION

Properties of Materials

Nonmetallics

(except Plastics and Rubber)

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Carbon and Graphite

Material →	Carbon	Graphite
PHYSICAL PROPERTIES		
Density, lb/cu ft	93.3–102.0	93.3–102.0
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	3–5	70–86
Coef of Ther Exp (70–212 F), per °F	1.3–1.5 x 10^{-6}	1.0–1.3 x 10^{-6}
Specific Heat (100 F), Btu/lb/°F	0.18	0.18
MECHANICAL PROPERTIES		
Mod of Elasticity in Tension, psi	1.6–2.3 x 10^{6}	0.8–1.4 x 10^{6}
Tensile Strength, psi	900–1100	440–2000
Compressive Strength, psi	6300–9000	1700–7500
Flexural Strength, psi	2500–3000	800–4000
Hardness (Scleroscope)	60–90	20–45
ELECTRICAL PROPERTIES		
Electrical Resistivity (68 F), microhm-cm	3500–4600	800–1300
Contact Resistance, ohms/sq in.		
Against Carbon	0.0058, 0.0026, 0.0017[a]	—
Against Copper	0.0133, 0.0093, 0.0042[a]	0.000704, 0.000315, 0.000162, 0.0000555[b]
Against Brass	0.038, 0.012, 0.0052[a]	0.00092, 0.000214, 0.000109[c]
Against Aluminum	0.138, 0.078, 0.015[a]	0.0448, 0.0067, 0.0020[c]
Against Graphite	—	0.000473, 0.000175, 0.000064, 0.000031[b]
Against Steel	—	0.01309, 0.00438, 0.00177, 0.000737[b]
FABRICATING PROPERTIES	Powdered material mixed with binder and shaped by molding under pressure or by extrusion, then baked above 1800 F	
CHEMICAL RESISTANCE	Carbon begins to oxidize in air at approximately 630 F and graphite at approximately 810 F, although the rate of oxidation is not rapid even at high temperatures. With a steam or a carbon dioxide atmosphere, temperature can be raised above a red heat before excessive oxidation occurs. Alkalis in solution do not attack these materials but fused hydroxides and carbonates attack them at high temperatures. They are not attacked by dilute acids, including hydrofluoric, but strongly oxidizing chemicals will attack them	
USES	Mechanical: sealing rings, pump and valve parts, bearings, pistons, and piston rings. Electrical: battery carbons, contacts, welding carbons, anodes, brushes for electrical machines. Refractory: linings, molds, continuous casting dies, furnace boats. Chemical: pipe, pumps, fittings, heat exchangers, valves, towers and accessories, porous filtering media	

[a]Pressures of 5, 25 and 75 psi, respectively.
[b]Pressures of 25, 150, 400 and 1000 psi, respectively.
[c]Pressures of 25, 150 and 400 psi, respectively.

Carbides

Type ➡	Beryllium Carbide (Be_2C)	Titanium Carbide (TiC)	Silicon Carbide (SiC)	Columbium Carbide (CbC)	Tantalum Carbide (TaC)
Hardness (mohs)	9+	8–9	9.2	9–10	9+
Electrical Resistivity, ohm-cm[a]	1.1	1.05×10^{-4}	107–200	7.4×10^{-5}	2×10^{-5}
Ther Cond (68–795 F), Btu/hr/sq ft/°F/ft	12.1	9.9[a]	24.1	8.23[a]	12.8[a]
Coef of Ther Exp (77–1472 F), per °F	5.8×10^{-6}	4.1×10^{-6}	2.6×10^{-6}	—	4.6×10^{-6}
Compressive Strength, psi[a]	105,000	109,000	82,000	—	—
Modulus of Rupture, psi[a]	16,000	—	4000	—	—
Thermal Shock Resistance (air quenched), cycles at designated temperature range (F)	4 at 2000–1470	—	100 at 2500–77	—	—
Fabrication Methods	Hot pressing, steel die pressing and sintering, hydrostatic pressing and sintering	Hot pressing, steel die pressing and sintering	Hot pressing, steel die pressing and sintering, extrusion and sintering, slip casting	Hot pressing, steel die pressing and sintering	Hot pressing, steel die pressing and sintering

Type ➡	Boron Carbide (B_4C)	Tungsten Carbide ($W_2C^{(\beta)}$)	Tungsten Carbide (WC)	Vanadium Carbide (VC)	Zirconium Carbide (ZrC)
Hardness (mohs)	9.3	9–10	9+	9–10	8–9
Electrical Resistivity, ohm-cm[a]	0.30–0.80	8.1×10^{-5}	1.2×10^{-5}	1.56×10^{-4}	6.34×10^{-5}
Ther Cond (68–795 F), Btu/hr/sq ft/°F/ft	16.9–48.4	—	—	—	11.9[a]
Coef of Ther Exp (77–1472 F), per °F	2.5×10^{-6}	3.3×10^{-6}	3.4×10^{-6}	—	3.7×10^{-6}
Compressive Strength, psi[a]	414,000	—	—	89,000	238,000
Modulus of Rupture, psi[a]	44,000	—	—	—	—
Thermal Shock Resistance (air quenched), cycles at designated temperature range (F)	½ at 1830–86	—	—	—	—
Fabrication Methods	Hot pressing, extrusion and sintering	Hot pressing	Hot pressing, steel die pressing and sintering	Hot pressing	Hot pressing, steel die pressing and sintering

[a]Room temperature.

Whiteware Ceramics (Industrial)

Type →	Alumina	Cordierite	Forsterite
PHYSICAL PROPERTIES			
Specific Gravity	3.2–3.8	2.29–2.65	2.9
Ther Cond, Btu/hr/sq ft/°F/ft	9.7–14.0	0.97–2.40	1.94–2.40
Coef of Ther Exp, per °F			
68-212 F	2.77–3.66 x 10^{-6}	2.08 x 10^{-6}	4.72 x 10^{-6}
68-932 F	3.61–4.05 x 10^{-6}	1.68 x 10^{-6}	5.40 x 10^{-6}
Thermal Shock Resistance	Good	Good	Moderate
Te Value, F[a]	1472–>1832	1436	680–>1832
Temp Coef of Capacitance Chg[b]	—	420	—
Water Absorption, %	0.00–0.01	0.02–3.2	0.00–0.02
Gas Permeability	Gas-tight 0.010 in. thick	—	Gas-tight 0.010 in. thick
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	35–41 x 10^6	7 x 10^6	—
Mod of Rupture, psi	40–48 x 10^6	6.8 x 10^6	19.0 x 10^6
Tensile Strength, 1000 psi	20–35	3.0	10.0
Hardness (Mohs)	8.5–9.0	7	7.5
Impact Strength (Charpy), in.-lb			
¾ In. Dia	—	7.4	7.5
½ In. Dia	6.3–7.0	4.4	2.4–4.0
Flexural Strength, 1000 psi	40–62	15	20
Compressive Strength, 1000 psi	140–420	52–95	80–85
Transverse Strength, 1000 psi	30–45	—	—
ELECTRICAL PROPERTIES			
Volume Resistivity, ohms/cu cm			
68–77 F	1.0–10 x 10^{14}	$>10^{14}$	$>10^{14}$
212 F	3.4–20 x 10^{12}	—	5.0 x 10^{13}
572 F	1.4–60 x 10^{10}	—	7.0 x 10^{11}
932 F	1.0–10 x 10^8	—	1.2 x 10^{10}
1292 F	3.0–180 x 10^6	—	1.0 x 10^8
1652 F	4.0–600 x 10^5	—	3.0 x 10^6
Dielectric Strength, v/mil	250–850	140–230	250
Dielectric Constant			
60 Cycles	—	—	6.3
1 Mc	7.8–9.5	4.02–6.23	6.2–6.5
100 Mc	—	—	6.1
10,000 Mc	8.0–9.4	—	5.8
Dissipation Factor			
60 Cycles	—	—	0.0014
1 Mc	0.0003–0.0010	0.0010–0.00930	0.0002–0.0004
100 Mc	—	—	0.0003
10,000 Mc	0.0008–0.0014	—	0.0010
Loss Factor			
60 Cycles	—	—	0.009
1 Mc	0.0027–0.0078	0.0297–0.0579	0.001–0.002
100 Mc	—	—	0.002
10,000 Mc	0.0075–0.0130	—	0.0058
HEAT RESISTANCE			
Max Rec Svc Temp, F	2012–3002	—	1832
USES	Spark plugs, electronic equipment, certain refractory applications, high-frequency equipment, vacuum tube envelopes, metallizing applications	Aircraft firewall connectors, appliance coil supports and terminal blocks, automotive heater cores, hot point insulators, brazing fixture parts, foundry parts, fuel burner tips, thermostat controls	Very low loss insulators, ceramic-to-metal seals (close tolerances obtainable by grinding)

[a]Te value is the temperature at which a cubic centimeter of the material has a resistance of 1 megohm.
[b]77-185 F, parts per million.

Whiteware Ceramics (Industrial)—concluded

Type →	Standard Electrical	Steatite	Zircon
PHYSICAL PROPERTIES			
Specific Gravity	2.37–2.53	2.5–2.92	3.43–3.86
Ther Cond, Btu/hr/sq ft/°F/ft	0.87–1.57	1.45–1.94	2.88–3.61
Coef of Ther Exp, per °F			
68–212 F	2.00×10^{-6}	$3.33–3.99 \times 10^{-6}$	$1.31–1.84 \times 10^{-6}$
68–932 F	2.70×10^{-6}	$4.52–5.50 \times 10^{-6}$	$2.09–2.16 \times 10^{-6}$
Thermal Shock Resistance	Fair	Moderate	Good
Te Value, F[a]	680–842	824–1544	1292–1598
Temp Coef of Capacitance Chg[b]	630	120	175
Water Absorption, %	0.0–0.1	0.0–1.0	0.0–9.0
Gas Permeability	Gas-tight	—	—
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	10	13–16	21
Mod of Rupture, psi	11.3	19.3–22.2	9.3–24.0
Tensile Strength, 1000 psi	2.5–7.0	4.8–15.0	4.5–12.0
Hardness (Mohs)	7.0–7.5	7.5	8
Impact Strength (Charpy), in.-lb			
¾ In. Dia	8.2	10.5–14.0	8.9–11.4
½ In. Dia	—	3.8–5.0	5.50–5.64
Flexural Strength, 1000 psi	5.4–12.0	11–20	18.5–22.0
Compressive Strength, 1000 psi	49.1–70.0	66–90	60–100
Transverse Strength, 1000 psi	11	—	—
ELECTRICAL PROPERTIES			
Volume Resistivity, ohms/cu cm			
68–77 F	$10^{13}–10^{15}$	$>10^{14}$	$>10^{14}$
212 F	1.2×10^{8} [c]	$0.21–>100 \times 10^{13}$	2.0×10^{13}
572 F	5.0×10^{6}	$0.6–800 \times 10^{8}$	5.5×10^{11}
932 F	4.0×10^{5} [d]	$0.32–300 \times 10^{6}$	5.5×10^{8}
1292 F	—	$2.3–500 \times 10^{6}$	1.4×10^{7}
1652 F	—	$7.0–680 \times 10^{3}$	8.2×10^{5}
Dielectric Strength, v/mil	55–300	145–280	60–290
Dielectric Constant			
60 Cycles	5.4–7.0	5.9–6.3	9.1
1 Mc	—	5.5–6.51	5.30–9.20
100 Mc	—	5.6–6.0	8.6
10,000 Mc	—	5.3–5.8	8.4
Dissipation Factor			
60 Cycles	0.0090–0.0112	0.0013–0.0150	0.0360
1 Mc	—	0.0011–0.0075	0.0007–0.0022
100 Mc	—	0.0009–0.0028	0.0012
10,000 Mc	—	0.0014–0.0054	0.0027
Loss Factor			
60 Cycles	0.053–0.060	0.008–0.090	0.327
1 Mc	—	0.007–0.0252	0.0041–0.0135
100 Mc	—	0.005–0.016	0.010
10,000 Mc	—	0.008–0.030	0.023
HEAT RESISTANCE			
Max Rec Svc Temp, F	1820	1832	2012
USES	Low voltage insulators, vitrified high voltage insulators, wire supports, outlet boxes, lightning arrestors, suspension insulators, x-ray rods and tubes	Aircraft insulators, appliance housings, electric line insulators, tube sockets, electrical instrument spacers and feed-through bushings, fuel igniters, camera and projector rollers, thermostat controls	Aircraft firewall connector plugs and glow plugs; electronic tube sockets, coil forms, spacers, brackets, printed circuits and plates; pump valves, plungers and seats

aTe value is the temperature at which a cubic centimeter of the material has a resistance of 1 megohm.
b77-185 F, parts per million. c392 F d752 F

Refractory Oxides

Type ➡	Alumina (Al_2O_3)	Beryllia (BeO)	Calcia (CaO)	Magnesia (MgO)	Silica (crystalline SiO_2)	Silica (vitreous SiO_2)
Melting Point, F	3660	4620	4710	5070	3140	—
Max Use Temp in Oxidizing Atm, F	3540	4350	4350	4350	3055	—
Hardness (Mohs)	9	9	4.5	6	7	—
Coef of Ther Exp, per °F	44×10^{-7} (68–2875 F)	52.8×10^{-7} (68–2550 F)	75.5×10^{-7} (68–2190 F)	77.8×10^{-7} (68–2550 F)	238.9×10^{-7} [a] (68–570 F)	2.8×10^{-7} (68–2280 F)
Ther Cond (at specified temperature and porosity), Btu/hr/sq ft/°F/ft	1.37 (2190 F, 23%)	9.52 (2190 F, 5–10%)	4.12 (1830 F, 9%)	1.47 (2190 F, 22%)	0.92 (2010 F)	0.80 (0.9%)
Thermal Shock Resistance	Good	Excellent	Fair	Fair	Poor to 600 F; excellent above 600 F	Excellent
Stability in:						
Reducing Atmosphere	Good	Excellent	Poor	Poor	Poor	Fair
Carbon	Fair	Excellent	Poor	Good	Poor	Good
Acid Slags	Good	—	Poor	Poor	Good	Good
Basic Slags	Good	Fair	Fair	Good	Poor	—
Metals	Good	Good	Fair	Fair	Poor	—

Type ➡	Thoria (ThO_2)	Zirconia (stabilized Zro_2)	Mullite ($3Al_2O_3$–$2SiO_2$)	Spinel (MgO–Al_2O_3)	Zircon (ZrO_2–SiO_2)
Melting Point, F	6000	4710	3330 [b]	3830	4390
Max Use Temp in Oxidizing Atm, F	4890	4530	3270	3450	3400
Hardness (Mohs)	7	7–8	6–7	8	7.5
Coef of Ther Exp, per °F	52.8×10^{-7} (68–2550 F)	30.6×10^{-7} [c] (68–2190 F)	25×10^{-7} (68–2410 F)	50×10^{-7} (68–2280 F)	30.6×10^{-7} (68–2190 F)
Ther Cond (at specified temperature and porosity), Btu/hr/sq ft/°F/ft	0.0 (2190 F, 17%)	0.53 (2190 F, 28%)	1.55 (2190 F, 30%)	1.21 (2370 F, 36%)	1.21 (1830 F, 30%)
Thermal Shock Resistance	Poor	Fair	Fair	Poor	Good
Stability in:					
Reducing Atmosphere	Good	Good	Fair	—	Fair
Carbon	Fair	Fair	Fair	Fair	Fair
Acid Slags	Poor	Good	Good	Fair	Good
Basic Slags	Good	Poor	Fair	Good	Poor
Metals	Excellent	Good	Fair	—	Good

[a] Depends on crystalline form. At temperatures of 570 to 2010 F, value is 16.6 per °F.
[b] Incongruent.
[c] Depends on degree of stabilization.

Mechanical Felts

SHEET AND ROLL FELTS

Type[a] ↓	Nominal Density, lb/cu ft	Typical Applications	Classification[b]
SHEET FELT			
Rock Hard	43	Heavy duty grinding and polishing wheels, bumpers	32-S-1, 32-S-2, 32-S-3, 32-S-4
Hard	35	Polishing granite, marble, glass tumblers; marking pens	26-S-1, 26-S-2, 26-S-3, 26-S-4
Medium	27	Polishing lenses, mirror and plate glass, and wood; cash carrier heads, bumpers, ink rollers, punched wicks	20-S-1, 20-S-2, 20-S-3, 20-S-4
Soft	21	Wicks, washers, plugs, transfer rolls, polishing blocks	16-S-1, 16-S-2, 16-S-3, 16-S-4
Extra Soft	16	Fine and soft metal polishing, absorbent pads, shock mountings, antivibration pads	12-S-1, 12-S-2, 12-S-3, 12-S-4
ROLL FELT			
Back Check (F-1, F-2, F-3)	21	Washers, bushings, wicks, ink rolls and pads, door bumpers, polishing blocks, wheels and pads, antivibration and dampening pads, window channels, oil and grease shields	16-R-1, 16-R-2, 16-R-3
Extra Firm Pads (F-5, F-6, F-7)	16	Dust shields, wipers, grease-retaining washers, wicks, antivibration mountings	12-R-1, 12-R-2, 12-R-3
Firms Pads (F-10, F-11, F-12, F-13, F-15)	11.3	Grease and oil retainers, dust shields, sound deadening, chassis strips, pedal pads, dash liners	9-R-1, 9-R-2, 9-R-3, 9-R-4, 9-R-5
Soft Pads (F-26)	9.6	Packing and padding	8-R-16
Ball Bearing (F-50, F-51)	21	Ball and roller bearing oil retainers; small dust-excluding washers; gaskets, liners, other thin cut parts	16-RX-1, 16-RX-3
Lining (F-55)	16	Antisqueak strips; lining cemented to fiber board and metal panels	12-RX-3

[a]SAE Spec No. in parenthesis.

[b]Felt classifications are based on the construction, i.e., fiber blends or "mixes," and density of the material. Several types, serving assorted uses, are customarily fabricated in each of the principal classes.
Standard nomenclature consists of a three-unit code in which the first number indicates the surface density (weight equivalent of 1 sq yd 1 in. thick); a letter ("S" for felts fabricated in sheets 36 x 36 in., "R" for felts fabricated in rolls 40 yd long and 60 or 72 in. wide); and a second number indicating the type of fiber composition, which has a basis in the U. S. Standard wool grade classification.

FILTER FELTS

Type[a] ↓	Nom Thk, in.	Density, lb/cu ft	Mullen Bursting Strength, psi[b]	Porosity, %	Air Permeability, cfm/sq ft/ 0.5 in. H_2O	Retention Efficiency, %[c]	Use
A (all wool)	1/32	10	50	93	280	45	Multilayer latex filter
B (all wool)	1/16	9	94	86	235	65	Air conditioning and pollen filtering
C (all wool)	1/16	11	125	86	130	76	Emulsion and dope
D (all wool)	1/16	13	130	86	105	88	Industrial air conditioning
E (all wool)	3/64	14	110	83	70	92	Air compressors; compressed air
F (cotton blend)	3/32	11	225	86	50	94	Cellulose lacquer and organic solvents
G (all wool)	3/32	17	220	66	30	96	Oil and fuel
H (all wool)	1/16	20	145	79	28	98	Industrial respirators and masks
I (all wool)	1/16	22	120	79	13	99	Biochemical air intake filters
J (silk blend)	1/16	30	235	62	2	100	Toxic dusts, fumes and mists

[a]Filter felts are made of special wool fiber blends chosen for their ability to make a felt of specific porosity, permeability and retention characteristics.

[b]ASTM D461-53.

[c]Retention of 0.7 micron mean dia mineral dust at rated permeability.

continued

Mechanical Felts—concluded

ROLL FELTS

SAE Spec No. ↓	Nom Thk, in.	Density, lb/cu ft	Breaking Strength, psi		Splitting Resistance (2-in. width), lb		Wool Content, %	Solubles, %[a]			Ash, %
			L[b]	W[b]	L[b]	W[b]		Carbon Tetra-chloride	Water	Com-bined	
F-1	¼	22.1	810	835	38	36	98	0.9	0.9	1.9	0.5
	½	19.3	850	720	42	44	98	0.8	1.5	2.3	0.6
F-3	¼	20.0	450	490	26	24	94	2.1	1.7	3.8	1.2
	½	20.1	475	550	32	29	95	2.1	1.2	3.3	1.0
F-5	¼	15.0	640	450	18	18	98	1.1	1.4	2.4	0.7
	½	15.4	640	565	21	19	97	0.6	1.6	2.2	0.6
F-10	¼	11.4	380	280	9	8	98	0.6	1.1	1.8	0.6
	½	11.0	400	325	8	8	98	0.5	1.3	1.8	1.0
F-11	¼	11.8	310	230	8	9	94	3.1	1.6	4.7	1.0
	½	12.2	300	240	9	9	94	3.7	1.2	4.9	0.9
F-15	¼	10.7	170	130	6	5	86	1.6	2.8	4.4	1.8
	½	11.2	180	130	4	4	88	1.7	2.8	4.5	1.9

[a]ASTM D 461-53. [b]L=lengthwise; W=transverse.

SAE Spec No. ↓	Abrasion Wear, % decr in thk[a]			Coef of Static Friction[b]				Oil Absorption and Capillary Flow (SAE 20 oil, 70 F)								Ther Cond (K), Btu/hr/sq ft/ °F/ft[c]
	Load, oz/sq in.							Oil Absorption (24 hr), % wt incr	Oil Wicking Rate, in./min lapsed time							
	3.8	7.0	10.2	Wood	Glass	Metal	Oiled Metal		5	10	15	30	60	90	120	
F-1	1.0	2.3	2.1	.37	.26	.22	.18	185	0.5	0.7	0.8	1.1	1.6	2.0	2.2	0.030
F-3	2.1	2.1	3.0	.37	.26	.22	.18	265	0.5	0.7	1.0	1.3	1.7	1.8	2.1	0.030
F-5	3.0	3.0	6.0	.37	.26	.22	.18	320	0.6	0.8	1.0	1.3	1.7	1.9	2.0	0.025
F-15	4.1	7.6	18.5	—	—	—	—	570	0.6	0.9	1.1	1.4	1.6	1.8	1.9	0.020

[a]Felt-to-felt, 10,000 rubs, 8-in. stroke. [b]Felt against material indicated.
[c]1-in. felt. Thermal and acoustical felts blended with Kapok fiber have tested values of 0.21 K factor and 0.80 sound absorption coefficient at 512 cps for 1-in. thicknesses of 3.2 lb per sq yd weight.

SAE Spec No.[a] →	F-1 (21)		F-3 (21)		F-5 (16)		F-10 (11.3)		F-11 (11.3)		F-15 (11.3)	
	Load, psi	Compr Set, %	Load, psi	Compr Set, %	Load, psi	Compr Set, %	Load, psi	Compr Set, %	Load, psi	Compr Set, %	Load, psi	Compr Set, %
Deformation, %												
10	21	1	13	1	6	1	4	1	4	1	3	1
30	110	4	93	6	41	4	9	3	15	4	10	4
50	480	11	420	12	215	10	58	9	72	9	64	10
80	27,900	53	21,200	55	7750	53	2380	40	2620	42	3420	42

[a]Density (lb per cu ft) given in parenthesis.

Natural Fibers

Type →	Cotton	Bast				Hard			Animal		
		Flax	Jute	Hemp	Ramie	Manila (abaca)	Sisal	Henne-quin	Wool	Horse-hair	Silk
FORM											
Fiber Length, in.	½–2½	6–40	10–60	40–80	15–25	20–40	24	20	1½–15	1–25	Filament
Fiber Width (avg) microns	17	16	17	20	47	19	19	20	28	100	11
Cross Section	Flat tube	Tube	Bunched cells	—	Flat tube	Bunched cells	Bunched cells	Bunched cells	Round	Round	Round
PHYSICAL PROPERTIES											
Spec Grav	1.55	1.50	1.48	1.48	1.55	—	—	—	1.30	1.30	1.60
Ten Str (70 F, 65% RH), 1000 psi	42–125	115	—	112–132	130	125	100–120	—	17–28	—	45–83
Wet, % of normal	120	—	Low	Low	High	High	Low	Low	79–97	—	75–95
Elong, %	3–10	3	—	2–6	3–6	2–3	2–2.5	—	25–50	—	13–31
Mod of Elast in Tension, psi	5.7–11	—	—	—	—	—	—	—	2.7–3.9	—	8.4–12.9
Stiffness, gm/grex	57–60	270	185	200	167	175	127	—	3.9	—	0.75–1.16
Strain Rec (2% strain unless noted), %	74, 45 at 5%	65	74 at 1%	—	52	—	—	—	99+, 63 at 20%	99, 63 at 20%	74
Toughness Index (relative work to rupture)	14	6	2	4	8	7	5	—	20	—	44
Strength Ratio (yarn to fiber)	0.45–0.60	0.38	0.35	0.36	0.45	—	—	—	0.50–0.55	—	—
Friction Coef (self)	0.30	—	—	—	—	—	—	—	0.20–0.50	—	0.26
Flammability	Burns	Burns	Burns	Burns	Burns	Burns	Burns	Burns	Slow burn	Slow burn	Burns
ENVIRONMENTAL PROPERTIES											
Acid Resistance											
Strong	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Res	—	Dissolves
Weak	Poor	Poor	—	Poor	—	—	—	—	Res	—	Fair
Alkali Resistance											
Strong	Exc	Good	Good	Good	Good	Good	Good	Good	Poor	Poor	Dissolves
Weak	Exc	Good	Good	Good	Good	Good	Good	Good	Poor hot	Poor	Poor
Organic Solvents	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res
Heat Effect	Good to 275 F	Good to 275 F	—	Good to 275 F	Good to 275 F	—	—	—	Good to 212 F	—	Disinte-grates at 340 F
Sunlight Effect	Weakens	None	None	None	None	None	None	None	Weakens	Weakens	Weakens
Microbiological Resistance	Poor	Very good	Good	Good	Exc	Good	Poor	Poor	Fair	Fair	Good

Synthetic Fibers

Type →	Regenerated Cellulose (rayon)				Cellulose Acetate (acetate)	66 Nylon			Fluorocarbon (Teflon)	Polyester (Dacron)
	Viscose									
	High Tenacity[a]	Regular	Cupram-monium	Fortisan 36						
COMPOSITION AND FORM										
Chemical Base	Regenerated cellulose		Regenerated cellulose	Saponified cell. acetate	Cellulose acetate	Polyamide			Polytetra-fluorethylene	Polyethylene terephthalate
Color	White	—	White	White	White	White			Brown	White
Fiber Width (avg), microns	10–15	10–43	11	—	11–46	10+			—	—
Cross Section	Irregular	—	Circular	Irregular	Irregular	Circular			Circular	Circular
PHYSICAL PROPERTIES										
Spec Grav	1.5	1.5	1.54	1.52	1.3	1.14			2.3	1.38
						Reg	High	Staple		
Ten Str 70 F, 65% RH, 1000 psi	85–95	29–47	33–42	138–155	20–25	67–85	89–108	60–66	44	85–106
Wet, % of normal	55–65	44–54	59	65–70	60–65	100	100	100	100	98
Elongation, %	10–20	15–30	10–17	6.2	23–30	26–32	19–24	37–40	24	12–40
Mod of Elast in Tension, psi	9.9–23.6	6.4–9.1	9.2	—	3–5	2.3–3.8	2.3–3.8	—	—	—
Stiffness, gm/grex	25	11	14	—	5.2	20	41–47	—	—	13–25
Strain Rec (2% strain unless noted), %	82	82	48 at 5%	—	94	100[b]	100[b]	100[b]	—	90–100
						75 at 20%				
Toughness Index (relative work to rupture)	25	19	14	—	19	56	52	—	Good	49–63
Friction Coef (Self)	0.19	—	—	—	0.29	0.14–0.16			Low	—
Flammability	Highly flammable		Highly flammable	Burns	Burns	Not support combustion			Fire resistant	Slow burn
ENVIRONMENTAL PROPERTIES										
Acid Resistance										
Strong	Decom-poses		Decom-poses	Poor	Decom-poses	Poor			Inert	Good at low temp
Weak	Strength loss		Decom-poses	Poor	Dissolved by some	Fair			Inert	Res
Alkali Resistance										
Strong	Swells		Swells	Swells	Saponifies	Good			Inert	Fair at low temp
Weak	Res (cold)		Res (cold)	Res (cold)	Res (cold)	Good			Inert	Good at low temp
Organic Solvents	Res		Res	Res	Dissolved by many	Generally insoluble			Inert	Res
Sunlight Effect	Weakens		Res	Res	Weakens	Weakens			Inert	Weakens
Microbiological Res	Attacked		Attacked	Attacked	Res	Res			Inert	Res

[a]Super Cordura.
[b]Delayed recovery up to two weeks.

Synthetic Fibers—concluded

Type →	Acrylic				Vinyl Derivative			Protein (Vicara)
	Orlon	Acrilan	Vinyon N	Dynel	Vinyon	Saran	Polyethylene	
COMPOSITION AND FORM								
Chemical Base	Polyacrylo-nitrile	Acrylic copolymer	Vinyl chloride-acrylonitrile copolymer	Vinyl chloride-acrylonitrile copolymer	Vinyl chloride-vinyl acetate	Vinylidene chloride	Polyethylene	Zein (corn protein)
Color	Cream	White	Light cream	Light cream	White	White	White	Beige-white
Fiber Width (avg), microns	—	—	—	—	16–18	50–1300	150+	15–30
Cross Section	Flattened tube	Flattened tube	Flattened tube, convoluted	Flattened tube, convoluted	Bar bell	Circular	Circular	Circular
PHYSICAL PROPERTIES								
Spec Grav	1.14–1.17	1.2	1.26–1.32	1.28	1.33	1.68–1.75	0.92	1.25
Ten Str								
70 F, 65% RH, 1000 psi	77	44–66	70–90	45–48	35–76	15–45	11–32	17.5–19
Wet, % of normal	95	80	100	100	100	100	100	45–55
Elongation, %	16	31	25–35	35	14–35	20–30 at break (oriented)	20–80	30–35
Mod of Elast in Tension, psi	—	—	—	—	3.5–4.5	0.3–1.7	—	—
Stiffness, gm/grex	28–30	8	10	7.9	22	20	2–12	2.8–3.4
Strain Rec (2% strain unless noted), %	85	80	97	97	99	95	90–95 slow	99 at 4%
Toughness Index (relative work to rupture)	44	32–40	45	48	30–36	—	30	18–21
Friction Coef (self)	—	—	—	—	0.19	—	—	—
Flammability	Slow burn	Slow burn	Self-extinguishing	Self-extinguishing	Not support combustion	Not support combustion	Slow burn	Burns
ENVIRONMENTAL PROPERTIES								
Acid Resistance								
Strong	Inert	Inert	Very res	Res	Res	Res	Res	Res to 10% conc
Weak	Inert	Inert	Very res	Res	Res	Res	Res	Decomposes
Alkali Resistance								
Strong	Attacked	Attacked	Res	Very res	Res	Res most	Res	Decomposes
Weak	Fair-good	Fair	Very res	Very res	Res	Res	Res	Res (cold)
Organic Solvents	Generally res	Very res	Good	Generally good	Poor	Generally res; swells	Generally good	Res
Sunlight Effect	Very res	Res	Slight str loss	Weakens	Res	Tends to yellow	Weakens	Res
Microbiological Resistance	Res	Res	Res	Res	Res	Res	Res	Res

Mineral Fibers

Type ➡	Glass			Asbestos			Ceramic (aluminum silicate)
	Standard	Micro		Chrysotile	Crocidolite	Amosite	
		Quartz	Glass				
COMPOSITION AND FORM							
Chemical Base	—	Silica glass	—	Hydrous magnesia silicates	Hydrous sodium and iron silicates	Iron and magnesium silicates	—
Color	Blue-white	Tan	—	Green, grey, white	Yellow-brown	Yellow-brown	Opaque white
Fiber Length, in.	Filament or staple	Staple	Staple	Crude ⅜–¾	Crude ⅜–¾	2–11 in.	Very short
Fiber Width (avg), microns	5–16	0.75	0.05–1.5	0.1	—	—	3
PHYSICAL PROPERTIES							
Spec Grav	2.54	—	2.54	2.4–2.6	3.2–3.3	3.1–3.25	—
Tens Str, psi	205–212	—	—	80–100	100–300	16–90	—
Elongation, %	2–3.7	—	—	Low	Low	Low	—
Abrasion Resistance	Poor	Poor	Poor	Fair	Fair	Fair	Poor
Moisture Abs, %	0.1	0.1	0.1	Contains 14% water	—	—	—
Specific Heat, Btu/lb/°F	0.157	—	0.157	0.266	0.201	0.193	—
Ther Cond (1000 F), 10^{-4} Btu/hr/sq ft/°F/ft	—	330–1000[a]	—	980[b]	—	—	190–1170[c]
Vol Res, ohm-cm	2×10^{11}	10^{15}	2×10^{11}	—	—	—	High
ENVIRONMENTAL PROPERTIES							
Acid Resistance	Resists all but hydrofluoric and hot phosphoric	Resists all but hydrofluoric and hot phosphoric	Resists all but hydrofluoric and hot phosphoric	Soluble to 57%	Good	Fair	—
Alkali Resistance	Dissolves in strong	Dissolves in strong	Dissolves in strong	Good	Good	Fair	—
Heat Resistance[d]							
Below 600 F	Exc	—	—	Fair, embrittles	Loses water at mod temp	Fair, embrittles	Little effect, keeps resilience
600 F	Softens	OK	Softens	8.4% loss in ten str	Embrittles, loses character	Embrittles, loses character	OK
800 F	NG	OK	—	26.7% loss in ten str	NG	NG	OK
1000 F	NG	Shrinks slightly	Max (as felt)	40.5% loss in ten str	NG	NG	OK
1200 F	NG	Shrinks slightly	NG	68% loss in ten str	NG	NG	OK
2000 F	NG	Shrinks slightly	NG	Embrittles, loses character	NG	NG	OK—still resilient
Fusing Temp, F	1500	2500	1500	2770	2180	2550	2800

[a] Felted; density 3 lb per cu ft.
[b] 75 F.
[c] Felted.
[d] NG = No good.

Woods (American)

Type[a] ↓	Specific Gravity	Static Bending Stress at Proportional Limit, psi	Max Crushing Strength (compression)	
			Parallel to Grain, psi	Perpendicular to Grain, psi
HARDWOODS (Deciduous)				
Ash, White	0.60	8900	7410	1410
Basswood	0.37	5900	4730	450
Beech	0.64	8700	7300	1250
Birch, Yellow	0.62	10,100	8170	1190
Cottonwood, Northern Black	0.35	5300	4420	370
Elm, Rock	0.63	8000	7050	1520
Gum, Sweet Red	0.49	8100	5800	860
Gum, Tupelo	0.50	7200	5920	1070
Hickory (bigleaf shagbark)	0.69	8900	8000	2220
Locust, Black	0.69	12,800	10,180	2260
Maple, Sugar	0.63	9500	7830	1810
Oak, Red	0.63	8400	6920	1260
Oak, White	0.68	8200	7440	1320
Poplar, Yellow	0.40	6100	5290	580
Walnut, Black	0.55	10,500	7580	1250
Willow, Black	0.37	3900	3420	480
SOFTWOODS (Coniferous)				
Cedar, Port Orford	0.42	7700	6470	760
Cedar, Eastern Red	0.47	3800	6020	1140
Cypress, Southern (bald)	0.46	7200	6360	900
Fir, Douglas (coast type)	0.48	8100	7420	910
Fir, Balsam	0.36	5200	4530	380
Hemlock, eastern	0.40	6100	5410	800
Hemlock, western	0.42	6800	6210	680
Pine, Eastern White (northern white)	0.36	6000	4840	550
Pine, Longleaf	0.58	9300	8440	1190
Pine, Ponderosa	0.40	6300	5270	740
Redwood (virgin)	0.40	6900	6150	860
Spruce, Sitka	0.40	6700	5610	710

[a]Samples air dried to 12% moisture content.

Glass (Industrial)

Type →	Fused Silica	96% Silica	Soda-Lime Glasses		Aluminum Silicate
			Plate	General Purpose	
PHYSICAL PROPERTIES					
Density, lb/cu in.	0.079	0.078	0.09	0.089	0.091
Softening Point, F	3050	2800	1330	1285	1675
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	0.80	0.80	0.53	0.53	—
Coef of Ther Exp (32–570 F), per °F	3.0×10^{-7}	4.5×10^{-7}	48×10^{-7}	51×10^{-7}	23×10^{-7}
Spec Ht, Btu/lb/°F	0.185	0.185	0.20	0.20	—
Elec Res (212 F), ohm-cm	$>10^{15}$	$>10^{15}$	—	4×10^{9}	$>10^{15}$
Power Factor (68 F, 1 mc), %	0.025	0.02–0.04	0.80	0.90	0.37
Dielectric Constant (68 F, 1 mc)	3.75	3.8	7.4	7.2	6.3
Thermal Stress Resistance, °F[a]	—	390	—	65	85
Thermal Shock Resistance, °F[b]	Very high	Very high	135	125	240
MECHANICAL PROPERTIES					
Mod of Elast in Tension, psi	10×10^{6}	9.7×10^{6}	$9–10 \times 10^{6}$	$9–10 \times 10^{6}$	12.7×10^{6}
Normal Work Stress (annealed), psi	1000	1000	1000	1000	1000
Highest Service Temp, F					
Annealed	1650	1500	900	840	1200
Tempered	—	—	550	480	840
THERMAL TREATMENT					
Annealing Temp (stress relief), F	2080	1670	1010	950	1315
FABRICATING PROPERTIES					
Workability	Glass can be ground or polished without great difficulty. Machining limited to sawing or drilling. Sawing readily accomplished with an impregnated wheel. Drilling is difficult, but is done with special carbide-tipped drills using kerosene as a lubricant				
Joining	Glass can be joined by heat sealing using a blast lamp, a gas torch or electric heating. Parts must have closely similar coefficients of expansion; otherwise, intermediate pieces having intermediate coefficients must be used. Glass-to-metal seals are also made by this latter process				
CHEMICAL RESISTANCE	Glass is attacked by hydrofluoric acid, hot concentrated phosphoric acid and strong alkalis. It is resistant to most other chemicals				
USES	Ultraviolet energy transmission, chemical apparatus, thermocouple protection tubes, laboratory apparatus	Ultraviolet energy transmission, chemical reaction vessels, thermocouple protection tubes, laboratory apparatus	Sheet and plate glass, molded glassware, bulbs for electric lamps, bottles, vials, fluorescent lamp tubing		

[a]Measured by subjecting the two sides of a tube or constrained plate to a temperature differential. Index is the differential that causes a stress of 1000 psi on cooler surface.

[b]Measured by heating squares of annealed glass, 6 by 6 by ¼ in., to a uniform temperature and dropping into cold water. Index is maximum temperature differential at which no breakage occurs.

Glass (Industrial)—concluded

Type ➡	Lead Silicate Glasses		
	Lamp Tubing	Thermometer	High Lead
PHYSICAL PROPERTIES			
Density, lb/cu in.	0.110	0.104	0.154
Softening Point, F	1160	1200	1075
Ther Cond (212 F), Btu/hr/sq ft/°F/ft	0.50	0.50	0.45
Coef of Ther Exp (32–570 F), per °F	50×10^{-7}	47×10^{-7}	51×10^{-7}
Specific Heat, Btu/lb/F	0.17	—	0.16
Electrical Resistivity (212 F), ohm-cm	10^{14}	—	$>10^{15}$
Power Factor (68 F, 1 mc), %	0.16	—	0.09
Dielectric Constant (68 F, 1 mc)	6.6	—	9.5
Thermal Stress Resistance, °F[a]	65	—	—
Thermal Shock Resistance, °F[b]	120	—	—
MECHANICAL PROPERTIES			
Mod of Elast in Tension, psi	9.0×10^6	—	7.6×10^6
Normal Work Stress (annealed), psi	1000	1000	1000
Highest Service Temp, F			
Annealed	720	750	720
Tempered	380	400	360
THERMAL TREATMENT			
Annealing Temp (stress relief), F	800	860	800
FABRICATING PROPERTIES			
Workability	Glass can be ground or polished without great difficulty. Machining limited to sawing or drilling. Sawing readily accomplished with an impregnated wheel. Drilling is difficult, but is done with special carbide-tipped drills using kerosene as a lubricant		
Joining	Glass can be joined by heat sealing using a blast lamp, a gas torch or electric heating. Parts must have closely similar coefficients of expansion; otherwise, intermediate pieces having intermediate coefficients must be used. Glass-to-metal seals are also made by this latter process		
CHEMICAL RESISTANCE	Glass is attacked by hydrofluoric acid, hot concentrated phosphoric acid and strong alkalis. It is resistant to most other chemicals		
USES	Lamp tubing, electrical and electronic applications, thermometer tubing, metal sealing		Electrical capacitors, x-ray shielding

[a]Measured by subjecting the two sides of tube or constrained plate to a temperature differential. Index is the differential that causes a stress of 1000 psi on cooler surface.

[b]Measured by heating squares of annealed glass, 6 by 6 by ¼ in., to a uniform temperature and dropping into cold water. Index is maximum temperature differential at which no breakage occurs.

Almost Anything

Design Properties of **FELT** by **FELTERS**

- Adaptable
- Strong
- Deadens noise
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- Perforates without fraying
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- Bondable
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can be made Better with

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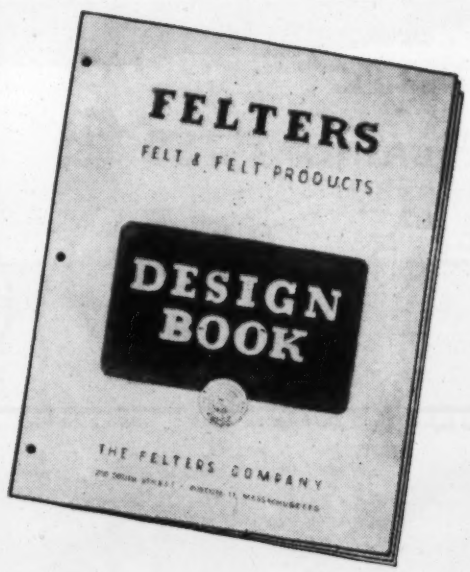

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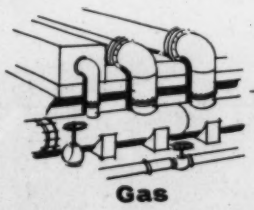

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Thick

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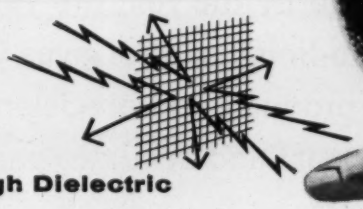

High Dielectric

GENERAL APPLICATIONS

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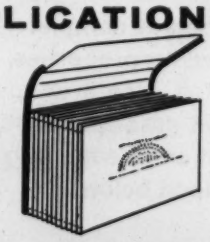
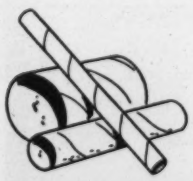


Long Wearing (Wallets)



Uniform Caliper (Paper Tubes)

Flexibility (Artificial Leather)

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There are a lot of new things being done with paper. Perhaps you would like to see a few of them without obligation. Just write us on your company letterhead . . . we'll take over from there.

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Manufacturers of Special Technical and Industrial Papers

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THIS IS GLASS

a bulletin of practical new ideas from Corning

New, neat way to heat

You can't buy this heater, *yet*. It's new—in fact so new in concept that what you see is a preliminary design sketch.

What makes it so unusual is the heating element it is designed around. Corning's *new* tubular heating element called HEAT SHEATH®.

This is what the basic unit looks like.

Essential components are: VYCOR brand glass tubing, colored *red;* capped leads; and a completely enclosed, extremely efficient wire heating element.

True . . . sheathed heating units are not new. But HEAT SHEATH offers a *combination* of important advantages to you who seek a compact, efficient, versatile source of heat.

Let's start with the glass tubing. It's made of a VYCOR brand glass that contains 96% silica. And silica in such amounts gives this glass the ability to cope with the usually adverse effects of both *high temperatures* and sudden *thermal shock*.

For example: You can take an object made of a VYCOR brand glass, heat it to 900° C., and then plunge it into ice water *without* cracking, crazing, shattering, or any change in form.

Next, consider the freedom of design this tubing offers . . . and how little space it requires. (O.D. is ⅝".) With a tentative rating of 500 watts per linear foot, you can provide desired heat with short sections "banked," or long, single units.

These units heat up fast, too, going from room temperature to maximum rating within 5 seconds. The warm red coloring is right in the glass—it can't wear out or off. (Note: Specific shade depends on wattage input and varies from a deep red to a cheerful ruby glow—colors that add *psychological* value to the heat.)

Naturally, the glass enclosure protects the heating element from dirt, dust, and accidental shorting. Fire hazard is reduced to zero. And the heating element itself has a life rating of 5,000 hours, *plus*.

Not interested in portable heaters at the moment? How about laundry dryers, broiling units, baseboard heating, air conditioning, industrial dryers? Maybe you've already thought of other possible applications.

If you're interested in finding out more about this compact, attractive, versatile, and challenging item, contact our Appliance Parts Sales Department. Write, wire, or phone.

Afterthought: There are 7 different glasses in the VYCOR brand group. We have a booklet that tells about them, gives details on thermal characteristics, radiant energy control applications, and such. The booklet is Bulletin B-91. Free with the coupon.

On the level

This intriguing (though difficult to show to advantage) bit of gadgetry is part of a *turn-and-bank* indicator for airplanes.

We don't make such instruments. We do supply the glass tubing, made from one of our PYREX brand glasses.

Those who do fashion instruments of this type find Corning a reliable, economical source for this tubing. Besides being free from visual defects this tubing is rugged, accurate and easily worked.

Astute makers of many things have discovered the practical and profitable road to glass components. They bring their wants to Corning.

The list of items and special glasses involved almost defies enumeration. (There are some 65,000 glass compositions in our files.) But a good start is a pleasant book called "This is Glass." Free. And/or drop us a line briefing your problem and we'll investigate and report promptly.

How to prevent TV sunburn

Those who perform in front of TV cameras are occasionally subjected to an occupational hazard called "television sunburn."

Cause of this unsought skin tinting is the intense heat generated by the big lights used to illuminate sets.

Now set the stage for another problem: Telecasting during the *summer* from a barn-like structure that has defied every effort of those versed in the art of air conditioning.

This "*double trouble*" is what the producers of a popular show, called "Grand Ole Opry," faced last summer. Putting the show on from Ryman Auditorium in Nashville, Tennessee, loomed as quite an ordeal.

Enter here a sensitive and knowledgeable person. His suggestion: Try PYREX brand infrared reflecting glass.

Sheets of this glass were placed in front of the lights with simple brackets. Here's what the setup looked like:

Heat output was reduced some 50%. Yet this PYREX brand infrared reflecting glass still transmitted 75% of the wanted light.

Conclusion: Where there's a knotty problem you'll often find a Corning glass to solve it. A number of good examples are detailed in Bulletin PE-34, a concise reference on infrared, sight glasses, flat glasses and sundry other useful items. A check in the coupon brings it to you.

Corning means research in Glass

CORNING GLASS WORKS, 50-10 Crystal Street, Corning, N. Y.

Please send me the following material: Bulletin B-91, "VYCOR brand Industrial Glassware by Corning" ☐; Bulletin PE-34, "Corning Flat Glasses" ☐; Illustrated booklet, "This is Glass" ☐.

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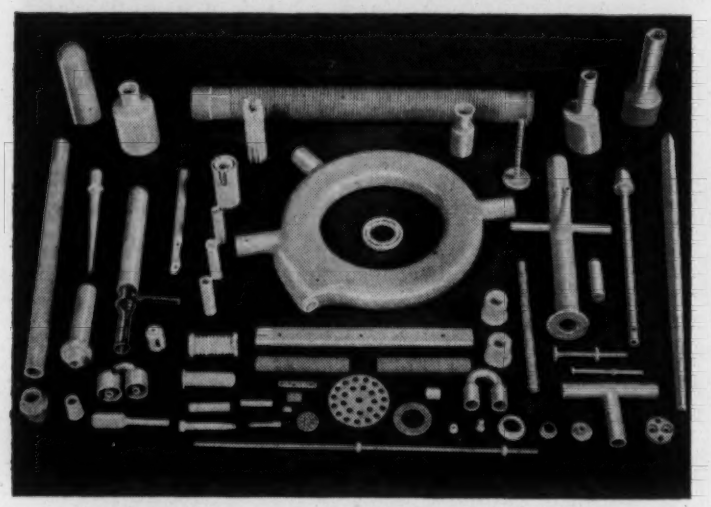

● Got a heat, abrasion or corrosion problem connected with your application? Try ceramics! Instrument manufacturers, scientists, physicists, research workers and specialized producers are applying McDanel Industrial Ceramics to a wide variety of difficult applications with success. Our trained ceramists will work with you to develop design, special dies, specially balanced bodies and mixes . . . even new processes to suit your particular need. Try ceramics! Write today!

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● Write today for information relating to your specific requirements to Graphite Specialties Corporation, 64th Street at Pine Avenue, Niagara Falls, New York.

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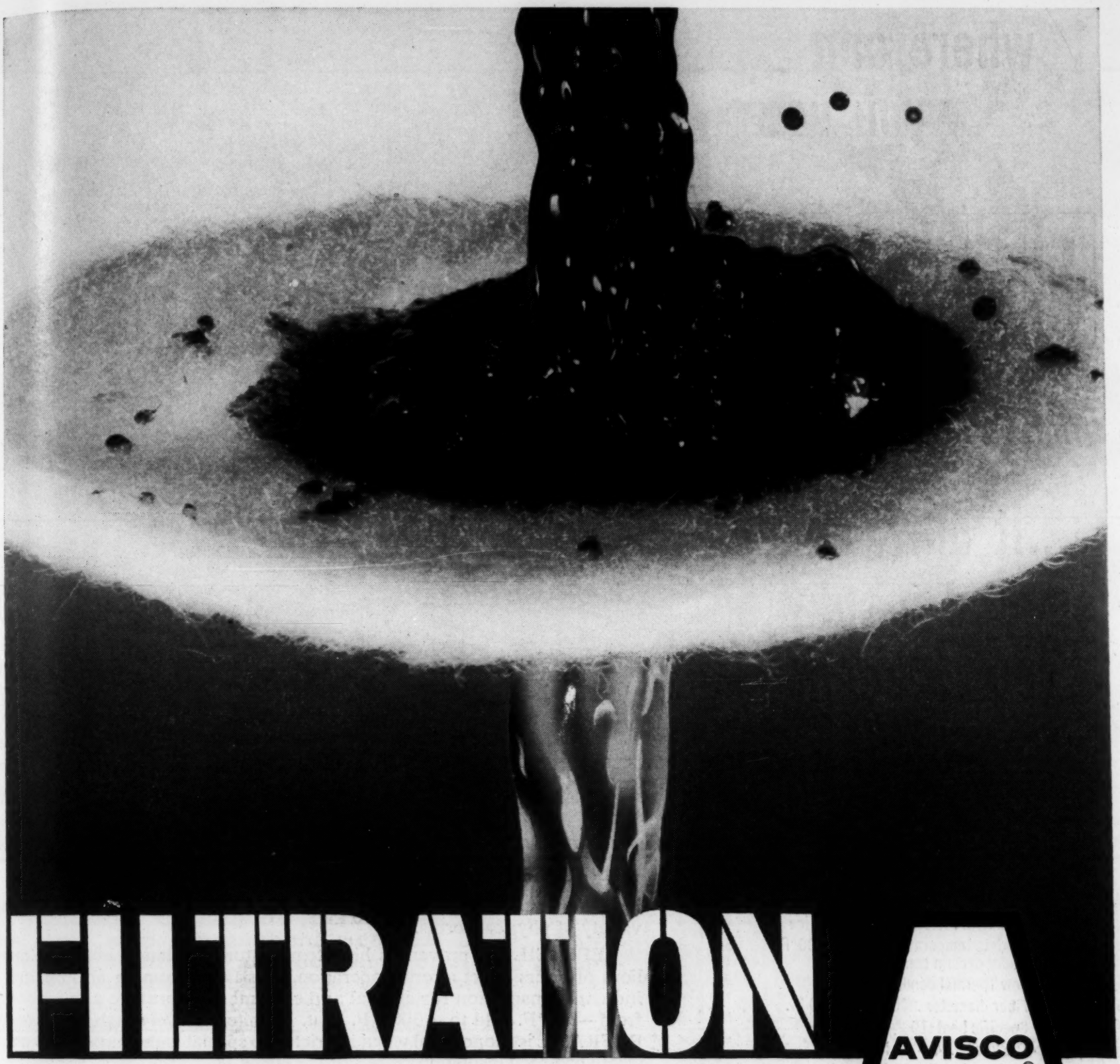

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What makes rayon superior in performance yet lowest in cost for all types of smoke, air and liquid filtration?

Man-made—First of all, rayon is a man-made fiber. That means its physical properties can be manufactured to meet specific filtration needs. Fiber size, weight, roughness and length can be carefully controlled during production so that the finished filter is tailored to do the exact job for which it was created. Further, rayon can be "crimped" or bent into tiny waves that increase the number of filter traps.

Non-channeling—Next, a filter made from crimped rayon staple does not channel—that is, the fibers form a barrier that keeps air, smoke or liquid from following straight paths.

Hooks and holds—The rayon fiber is rough-edged, too—tends to hook and hold passing impurities. Slicker fibers can't snag particles like rayon can.

Even-staining—Rayon stains evenly. This may be attributed only to high uniformity of filtration.

Controlled fiber length—The length of the rayon fiber is controlled, assuring better filtration at a steady, uniform flow. Uncontrolled lengths cause channeling and clogging, reduce efficiency.

Variety of densities—Most important, practically any filter density can be produced with rayon, due to the infinite webbing patterns possible with different deniers.

Low cost—All these superior filtering qualities come to you at lower cost than with any other filter fiber. Techniques for mass-producing rayon, developed over the past half century by American Viscose Corporation, make this low price possible.

Rayon filters simply cannot be matched for versatility, efficiency and low cost. We would be happy to show you further how you can use rayon filters for a more profitable business.

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High Temperature Insulation

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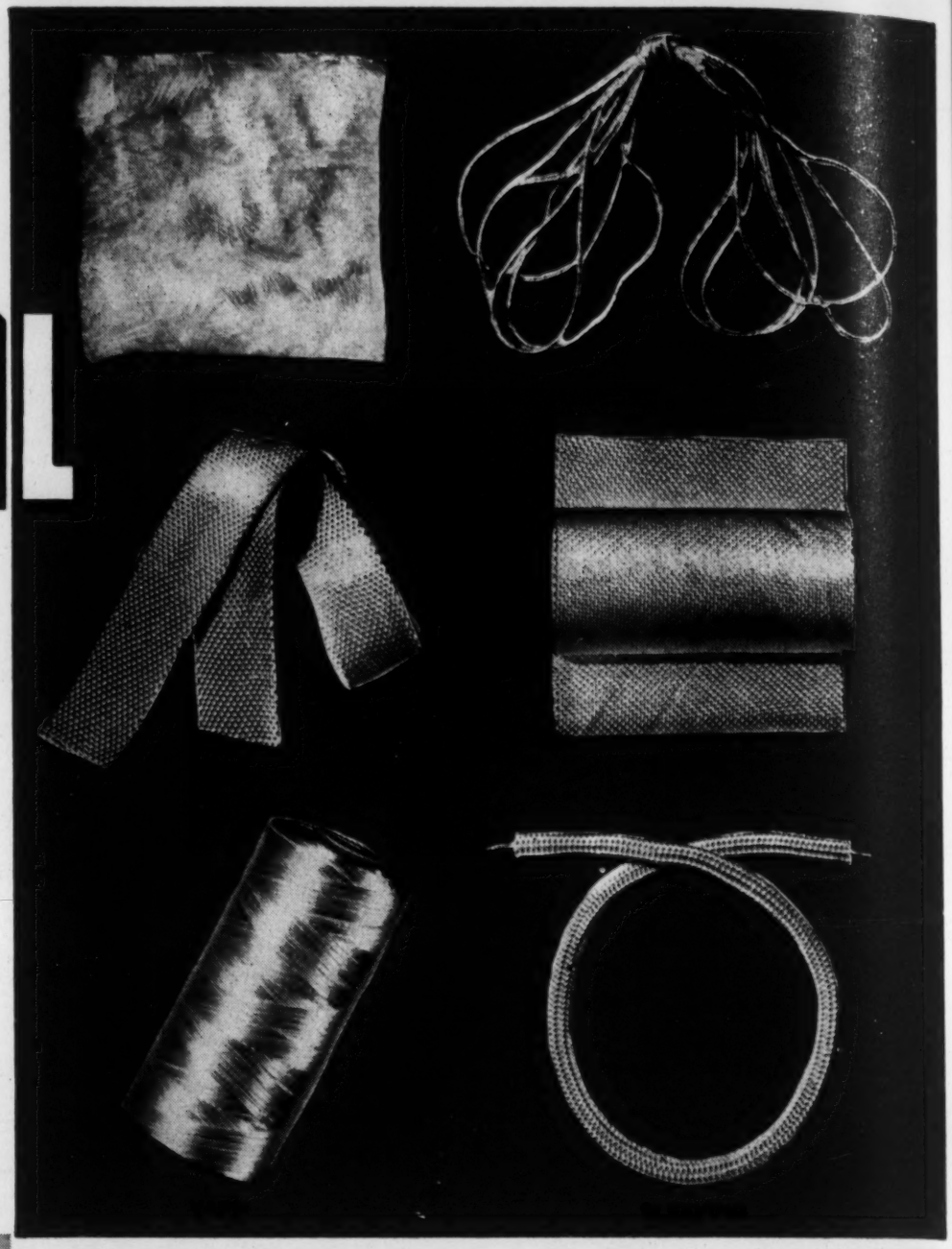

REFRASIL PROPERTIES:

- Chemical resistance of pure silica
- Resists temperatures up to 3000°F. under certain conditions
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- Thickness .14—.15 in.
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- Filtration of corrosive materials
- Removable, insulating blankets
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- Electric muffle furnaces
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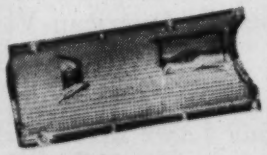
REFRASIL INSULATING BLANKETS:

"WRAP-AROUND"



"PRE-FORMED"

WHAT IS REFRASIL? REFRASIL is a highly efficient fibrous silica insulation material, extremely light in weight and bulk and made in a variety of physical forms.

REFRASIL has proven its high temperature insulation ability in millions of hours of jet aircraft operation. It is fast becoming an important industrial insulation for critical and extreme temperature applications from −300°F. cold to +3000°F. heat. Despite relatively high initial cost, REFRASIL is economical when restricted to special high temperature uses where ordinary insulation materials fail.

If you need an efficient, lightweight 2000°-3000° insulating material in bulk fiber or any of the physical forms shown, REFRASIL may be your best answer. For your *special* high temperature insulation problems, our research and development engineers are only a phone call away. Call or write for complete engineering information and free samples of REFRASIL, for your own testing.

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Eliminate virtually all problems encountered with conventional materials in 3 major reinforced plastic fields and are ideal for filtration, high temperature bearing seals, gasketing. The new FEUTRON mechanically interlocked felts, recently developed by American Felt Company, are of 100% synthetic fiber construction. Although particularly suited to the reinforced plastic (low pressure) field their uses are practically unlimited.

The three reinforced plastic fields in which FEUTRON felts are especially suited: electrical and electronic equipment, as overlays in fiberglas mat reinforced bodies, where chemical or corrosion resistance is necessary.

FEUTRON FACTS

1. **Exceptional chemical resistance with thermal stability to 300F.**
2. **Non-hygroscopic and biologically stable.**
3. **Produces a smooth, fiber-free surface in finished product.**
4. **Three dimensional strength properties.**
5. **Excellent uniformity of weight and thickness.**
6. **Good draping and tailoring properties.**
7. **Good resin pickup (wettability) due to large amount of fiber surface available.**
8. **Good resin-to-fiber adhesion.**
9. **High strength and elongation properties which may eliminate the need for pre-forming in deep draw applications, and prevent tearing in vari-shaped molded applications.**
10. **Excellent dielectrical properties.**

FEUTRON FELTS are available in DACRON** . . . ACRILAN*** . . . ORLON† . . . DYNEL†† . . . NYLON . . . ARNEL††† . . . VINYON‡ . . . VICARA‡‡

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††Union Carbide's acrylic fiber
†††Celanese Corp. trademark for its tri-acetate fiber
‡Union Carbide's Copolymer of polyvinyl acetate and polyvinyl chloride
‡‡Virginia Carolina Chemical Co. Zein Protein Fiber

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SUPPLIERS' LITERATURE

Finishes and Coatings

Chromate Coatings. Allied Research Products, Inc., No. 157. Series of data sheets on chromate conversion coatings used for corrosion protection, as a paint base, and for decorative finishing on magnesium, aluminum, copper, brass and bronze surfaces. Gives application data. (180)

Protective Metal Finishes. American Chemical Paint Co., 8 pp. Guide to chemical treatment of steel, iron, zinc, cadmium and aluminum. Lists metal products treated, object of coating, type of coating, method of application, and coating time and weight. (182)

Rhodium Electroplating. Baker & Co., Inc., 20 pp, illus. Shows applications of rhodium plating and discusses physical properties of the metal. (183)

Protective Coatings. Ceilcote Co., 8 pp, illus., No. C-150. Gives base formulations, chemical properties and adhesion characteristics of seven standard organic coatings. Includes simplified chart for selecting coatings. (184)

Decorator Flock. Cellusuede Products, Inc., 10 pp, illus. Describes flock and how it is used as a decorative finish. (185)

Chromizing Steel. Chromalloy Corp., 8 pp, illus., No. 34. Results of salt spray tests made on carbon, low alloy and stainless steels before and after Chromallizing. Briefly describes each test, listing the material, test procedure and results of the test. Also reports on a number of case histories where Chromallizing is being used. (186)

Metallic Coatings for Plastics. Coating Products. Attractive brochure describes the various coatings applied to plastics materials. Samples included. (187)

Nickel Plated Steel. Wickwire Spencer Steel Div., Colorado Fuel & Iron Corp., 12 pp. Describes electro-clad nickel plated products, manufacturing techniques and fabrication procedures. (188)

Chromate Sealer. Conversion Chemical Corp., No. P-40. How to use Kenvert No. 40, a chromate sealer for protecting aluminum against corrosion. (189)

Zinc Phosphate Coatings. Detrex Chemical Industries, Inc., 8 pp, illus. Describes phosphate coatings used as a base to protect paint finishes under severe corrosion conditions. (190)

Black Oxide Finish. Du-Lite Chemical Corp. Information on finishes for steel blackening. (191)

PVC Coatings. Firestone Plastics Co., 30 pp, illus. Information on six vinyl chloride resins for solution coatings. Characteristics of each resin are described, and a graph shows the solubilities of these resins in methyl ethyl ketone solvent. (192)

Electroless Nickel Plating. General American Transportation Corp. Describes Kanigen, a nickel plating process that does not require electrical equipment. (193)

Teflon Finishes. General Plastics Corp., 16 pp, illus. Four bulletins on the nonstick and physical properties of Teflon. (194)

Vinyl Lacquers. Davison Chemical Co., Div. of W. R. Grace & Co., 5 pp. Technical bulletin on use of Syloid 244 for flatting vinyl lacquers to give low gloss. (195)

Paints for Polystyrene. Logo, Inc., Div., Bee Chemical Co., 1 p. Guide to selection of paints for polystyrene. Lists type of application, finish and thinner. (197)

Multicolor Enamel. Maas & Waldstein Co., 2 pp, No. 520. Data sheet on industrial multicolor enamels. (198)

Corrosion Prevention. Metallizing Engineering Co., Inc., 4 pp, illus. Description of Metco systems and how these pure metallized zinc or aluminum coatings prevent corrosion. (200)

Protective Coatings. Michigan Chrome & Chemical Co., 8 pp, illus. Describes coating materials for tanks, molds and fixtures used in plating systems. (201)

Colored Silicone Finishes. Midland Industrial Finishes Co., illus. An interesting discussion of the applications of colored silicone finishes. (202)

Urethane Coatings. Mobay Chemical Co., 55 pp, illus. Comprehensive manual on the preparation and use of Mondur/Multron urethane coatings in electrical applications. (203)

Wrinkle Finishes. New Wrinkle, Inc., illus. Folder shows typical products utilizing Wrinkle finishes. (205)

Ceramic Coatings. Norton Co., New Products Dept., 10 pp, illus., No. CP11.3. Compares physical properties of aluminum oxide, zirconium silicate and zirconium oxide coatings with those of stainless steel. (206)

Phosphate Coating. Parker Rust Proof Co., 4 pp, illus. Use of nonmetallic Bonderite coating as a finish on tabulators, typewriters, furnaces and other products. (208)

Plastisol Coatings. Reynolds Chemical Products Inc., 14 pp. Outlines properties of plastisol coatings for plating racks, steel, bottles, gloves, ropes and wire. (209)

Strippable Coating for Plastics. Spraylat Corp., 4 pp, illus, No. M-1. Describes a strippable plastics coating designed for protecting acrylics and other plastics surfaces. Lists advantages and shows typical applications. (210)

Hard Surfacing Aluminum. Tiarco Corp., 4 pp, illus. Explains Hardalume process, a technique for providing a surface layer of hard chromium on aluminum. (211)

Porous Chromium Coatings. Van der Horst Corp., 12 pp, illus. Describes oil retaining, wear resistant chromium coating for bearing surfaces, cylinder walls and other applications. (212)

Insulating Varnishes. Micarta Div., Westinghouse Electric Corp., No. B-1050. Lists technical data and applications for a line of electrical insulating materials. Gives properties of treated papers, organic-varnished fabrics and combination insulations, organic-varnished glass fabric insulation, and silicone treated insulations. (213)

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DATA
SECTION

Properties of Materials

Finishes and Coatings

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Hard Coatings and Surfaces

Type ↓	Method of Application	Basic Metals That Can Be Coated	Nature of Hard Surface	Usual Thickness Range	Hardness	Major Characteristics
Hard Facing	Hard alloys applied by variety of welding processes, including gas metal arc and atomic hydrogen arc. Surface of metal brought to melting point of hard facing alloy. Parts may require preheat at 700–1200 F	Practically all ferrous metals. Some high-melting nonferrous alloys	Variety of ferrous and nonferrous alloys	1/16–1/4 in.	Wide range up to Rockwell A90, depending on alloy used	High hardness combined with varying degrees of resistance to abrasion impact, corrosion and heat, depending on alloy used
Carburized Surface	Carbon in solid, liquid or gas form introduced into metal surface by heating both in contact at temperatures above transformation range, generally 1450–1750 F	Carbon and alloy steels low enough in carbon content (<0.45%) to take up that element readily	Case high in carbon	0.005–0.25 in.	Approx Rockwell C62–64	High strength and toughness in core can be combined with extreme surface hardness
Nitrided Surface	Nitrogen introduced into surface by heating metal in contact with ammonia or other nitrogeneous material at 930–1050 F	Primarily special nitriding steels. Also medium carbon steels containing chromium and molybdenum, stainless steels, some cast irons	Case containing nitrides of various alloying elements	0.005–0.030 in.	Approx Rockwell C63–64 for molybdenum steel; 15N92 for 416 stainless and Nitralloy 135	High wear resistance, retention of hardness at elevated temperatures. Good resistance to certain types of corrosion
Cyanided or Carbonitrided Surface	Carbon and nitrogen introduced into surface by heating metal in liquid cyanide (cyaniding) or in carbonaceous and nitrogeneous (carbonitriding) both at 1200–1600 F	Same steels as used for carburizing	High carbon case containing nitrides	0.003–0.020 in.	Rockwell A80–81 for SAE 1010 steel	In general, same as for carburized cases
Siliconized Surface	Silicon introduced into surface by heating metal in contact with silicon carbide and chlorine at 1700–1850F	Low carbon(<0.25%), low sulfur (<0.04%) steels	Alloy case containing up to 14% silicon	0.005–0.010 in.	Rockwell B80–85	High resistance to wear, heat, corrosion
Chromized Surface	Chromium introduced into surface by heating metal in contact with chromium-containing powdered compound at 1500–1900 F	Low and high carbon steels, many alloy steels,stainless steels, tool steels, cast iron, iron powder parts	High chromium stainless steel or chromium carbide, depending on metal composition	0.5–2 mil	1600–2300 Vickers for chromium carbide case	High resistance to wear, abrasion, corrosion
Flame Hardened Surface	Surface structure changed by heating surface only with oxyacetylene flame above transformation range, followed by quenching	Any steel that can be hardened by conventional methods	Hardened surface structure. No change in chemical composition	0.06–0.25 in.	Max hardness depends on carbon content of base metal	High hardness, resistance to wear and abrasion
Induction Hardened Surface	Surface structure changed by heating surface only by means of electrical induction above transformation range, followed by quenching	Medium carbon steels, gray cast iron, pearlitic malleable and nodular cast irons	Same as flame hardened surface	0.015–0.125 in.	Max hardness depends on carbon content of base metal	Same as for flame hardened surface
Chromium Plate	Electrodeposition of chromium	Iron, steel, copper, nickel, zinc, aluminum, magnesium, titanium, brass	Chromium	Approx 1 mil max	Up to 1000–1025 Brinell	High hardness, excellent corrosion resistance, low coefficient of friction, nongalling and nonwetting
Nickel Plate	Electrodeposition of nickel	Iron, steel, copper, zinc, aluminum, magnesium, brass	Nickel	Up to 1/4 in.	150–800 Vickers	High wear, corrosion resistance
Rhodium Plate	Electrodeposition of rhodium	Most metals, including gold, silver, electrical contact materials	Rhodium	0.001–1 mil	540to640Vickers (20-gm load)	High hardness and wear resistance, attractive appearance
Hard Anodized Coating	Surface converted to metallic oxide or other inorganic compound by electrochemical process in which base metal is made anode in electrolyte	Most aluminum alloys and magnesium	Case consisting of oxides or other inorganic compounds of the base metal	Approx 1–5 mil	Difficult to assess by conventional methods	Better resistance to abrasion, erosion and corrosion than base metal
Sprayed Coating	Metal or ceramic layer applied by spraying molten or semimolten particles which fuse, cool and solidify on surface. Surface temperature ranges up to 800 F	Most commonly used metals	Bronze, various irons and steels, molybdenum, aluminum or zirconium oxide, zirconium silicate, tungsten carbide	Metals: up to 1/8 in. Ceramics: 0.005–0.050 in.	Up to 1350 Vickers for tungsten carbide	Extremely wide range of surface properties, depending on coating material

Chemical Conversion Coatings

Purpose and Type ↓	How the Coatings Compare	Metals That Can Be Coated*									
		Aluminum	Cadmium	Copper	Iron	Magnesium	Silver	Steel	Tin	Titanium	Zinc
To Improve Paint Bonding											
Phosphate	Rough crystalline structure provides excellent paint adhesion. Better paint bond than chromate coatings. Corrosion confined to limited area when paint film damaged	X	X		X	O		X	O		X
Chromate	Provides high corrosion protection because of nonporous structure. Paint adhesion generally not as good as with phosphate	X	X	O	O	X	O	O	O		X
To Improve Corrosion Resistance											
Anodic	Provides equal or better corrosion protection—at higher cost—than chromate	X				X					O
Chromate	Generally provides much better corrosion resistance than phosphate. Nonporous structure acts as moisture barrier. If coating is broken, inhibiting action of soluble chromate retards corrosion of basis metal	X	X	X	O	X	O	O	O		X
Phosphate	Not generally used alone for corrosion protection. When treated with oils, waxes or stains, however, it provides good protection, especially on ferrous surfaces	X	O		X			X	O		X
Oxide and Other	Do not provide as much protection as other conversion coatings, but cost is lower	O	O	O	O			O			O
For Decoration											
Chromate	Available in wide variety of natural and dyed colors. Colors are not as light-fast as in colored anodic coatings	X	X	X	O	X		O	O		X
Anodic	Can be colored with a large variety of dyes and pigments. Underlying metal can be used to impart attractive metallic sheen. Sealing required	X				X					O
Phosphate	Little decorative value except when painted	X	X		X	O		X	O		X
Oxide and Other	Black and blue-black coatings widely used to decorate ferrous, zinc and cadmium surfaces. Considerable number of colors producible on copper and aluminum	X	X	X	X			X			X
To Aid In Cold Forming											
Phosphate	By preventing metal-to-metal contact, lubricated coating facilitates deep drawing, cold heading, extrusion, and wire and tube drawing	X			X			X			X[b]
Oxide and Other	Special coatings have been developed for titanium									X	
To Improve Wear Resistance											
Phosphate	Maintains continuous oil film between bearing surfaces; prevents welding of surfaces under load				X			X			
Anodic	Hard anodic coating with greater thickness and weight than conventional anodic coatings increases wear and abrasion resistance	X				X					

*X—Metals most commonly treated for purpose listed. O—Metals less commonly treated. [b]Electroplates.

Chromium Electroplates

TYPES OF PLATES

Chromium electrodeposits consist of two principal types: decorative and hard chromium plates, and their modifications. Both principal types are deposited from the same plating baths and are distinguishable only by their different thicknesses.

Decorative chromium. Decorative plates are quite thin (0.01-0.02 mil), are usually deposited over a nickel plate, and are used primarily because of their bright, nontarnishing finish.

Some typical applications of decorative chromium plate are: automobile trim and hardware, plumbing fixtures, household appliances and hardware, sanitary fixtures, tools and jewelry.

Hard chromium. These coatings are comparatively thick (0.1 to 15 mils) and are used primarily in engineering applications because of their extreme hardness, low coefficient of friction, chemical resistance, and nongalling and nonwetting properties. Undercoats of nickel or copper are sometimes used for added corrosion resistance.

Applications of hard chromium plate are quite extensive. Some principal applications are gages, tools and machine tool parts—both new parts and worn parts to be salvaged. Taps, drills, saws, milling cutters and burnishing tools have been successfully plated. Molds for plastics and rubber are plated to reduce wear and sticking and to improve product appearance. Gun barrels, pump shafts, engine cylinders, drawing dies, calender rolls and engraving dies are other applications.

Porous chromium. This type of plate is essentially a hard chromium plate containing carefully controlled pits or channels designed to improve the lubrication properties of bearing surfaces. Plates range in thickness from 3 to 15 mils. Beneath its outer surface the plate is no more porous than ordinary hard chromium plate.

Porous chromium plate consists of three principal types: mechanical, pit and channel. The mechanical type is produced by hard chromium plating and subsequently polishing a roughened, cut or engraved basis metal. The polished tops of the grains form the bearing surface and the depressions between the grains hold the lubricating oil. The pit and channel types are produced by chemical or electrochemical etching of the chromium deposit. Plating conditions are controlled to produce latent chromium deposits predisposed to the development of a particular size and type of network pattern during etching.

The pit or pocket type of porous plate is generally used on diesel engine cylinders and industrial gasoline and gas engines, pumps and compressors. The channel type of deposit is generally used on aircraft cylinders. Thickness and porosity of both types of deposits depend on the size and type of engine.

Crack-free chromium. Crack-free plates, deposited in self-regulating baths, have recently achieved considerable importance. These plates have two principal advantages: 1) their dense, uniform, crack-free structure provides excellent resistance to corrosion and thermal shock, and 2) self-regulation of the bath practically eliminates maintenance problems. In many applications the coating can be deposited directly on the basis metal without prior nickel or copper plating. Deposits are producible in a bright or gray, matte finish. Applications for crack-free plate are generally the same as for decorative and hard chromium plates.

PHYSICAL AND MECHANICAL PROPERTIES

Density, lb/cu in.	0.25
Melting Point, F	3452
Ther Cond, Btu/hr/sq ft/°F/ft	157.3
Specific Heat, Btu/lb/°F	0.1039
Coef of Ther Exp, per °F	14.6×10^{-6}
Reflectivity, %	
Visible Light	62-72
Ultraviolet Light	55-70
Infrared Light	62-88
Elec Resistivity (82 F), microhm-cm	
As Deposited	50-60
After Annealing	13
Hardness (Brinell)	1000 max
Sliding Coef of Friction	
Cr-Plated Steel vs Cr-Plate Steel	0.12
Cr-Plated Steel vs Babbitt	0.13
Cr-Plated Steel vs Steel	0.16

BASIS METALS PLATED

Aluminum and its alloys
Copper and its alloys
Iron and steel
Magnesium alloys
Nickel and its alloys
Titanium and its alloys
Zinc and its alloys

TREATMENT AFTER PLATING

Recent work indicates that heat treatment may not be desirable in applications where fatigue is a factor. In some applications, however, heat treatment may be required to relieve strains caused by occluded hydrogen. For example, hardened high carbon steel parts of thin cross section, such as steel tools, generally require heat treatment after plating. Parts are placed in an oil bath or oven at 250-350 F for 1 to 3 hr. Immersion in boiling water for extended periods has also proved effective.

BASIS METAL PRETREATMENT

Decorative plate. In general, bright nickel work that does not require buffing can be placed, still wet, directly in the chromium plating solution. Buffed surfaces, however, must be cleaned to remove grease, dirt and oxide films. Cleaning is performed as follows:

1. Electrolytic alkaline cleaning with basis metal as cathode. Treatment performed at 6-12 v and 175-200 F long enough to remove dirt and grease.
2. Warm water rinse (120 to 160 F).
3. Cold water rinse.
4. Acid dip at room temperature to remove surface oxide. Treatment can be performed in sulfuric acid (20% by vol) solution; in muriatic acid (30-50%) solution; or by using basis metal as cathode (4-6 v) in electrolytic sulfuric acid (5%) solution.
5. Cold water rinse.

Hard chromium plate. Basis metal pretreatment is especially important for hard chromium plates since the coating does not fill in pits and scratches and tends to reproduce the surface on which it is deposited. Though no definite sequence of operations can be given for all types of work, the following pretreatment is typical for ferrous surfaces:

1. Preliminary grinding to remove scale, pits and scratches. (This step is not required for smooth surfaces.)
2. Preliminary cleaning by vapor degreasing or washing in petroleum spirits to remove oil or grease.
3. Electrolytic cleaning in hot alkali cleaner.
4. Cold water rinse.
5. Electrolytic etch to remove light rust and other iron compounds, and to produce a slightly roughened surface that will promote adhesion of chromium. Sulfuric or chromic acids are most commonly used; if shape of parts causes entrapment of sulfuric acid with consequent danger of contaminating chromium plating bath, chromic acid etch may be preferred. Parts may be transferred directly from chromic acid bath without rinsing.

   Etching is sometimes produced in chromium plating bath by reversing current so that work is made anodic. After etching (about ½-1 min), current is reversed and plating started. Thin oxide films can also be removed by dipping work in dilute sulfuric or hydrochloric acids. This method does not appreciably dull the luster of highly polished surfaces; however, it does not promote adhesion as well as other etches.

PLATING BATHS

Conventional chromium plating baths contain only two essential constituents: chromic acid and a sulfate catalyst acid radical. Successful deposition is determined by the weight ratio of chromic acid to sulfate; this ratio should be kept between 50:1 and 250:1, preferably at about 100:1. Too small a catalyst content can result in no deposition at all or else produce brown oxide stain. Similarly, too high a catalyst content produces a bath with poor or no throwing power. Two typical formulations are:

Concentrated		Dilute	
Chromic acid (CrO_3)	53 oz/gal	Chromic acid	33 oz/gal
Sulfate	0.53 oz/gal	Sulfate	0.33 oz/gal

The dilute bath has a slightly higher current efficiency than the concentrated bath. However, because of its lower conductivity, the dilute bath usually requires a higher voltage for a given current density. Also, because of its low sulfate content, the dilute bath is more sensitive to the addition or removal of catalyst from drag-in and drag-out.

A self-regulating high speed chromium plating solution is gaining wide acceptance, especially for high production decorative plating using automatic equipment. It consists of a proprietary solution containing mixed acid radicals which automatically regulate themselves. The high cathode current efficiencies and the bright plates produced at high current densities result in high plating rates—more than twice those of conventional solutions, it is claimed.

THICKNESS OF DEPOSITS

In general, thickness of plates for decorative applications ranges from 0.01 to 0.02 mil. Following are some typical thickness recommendations (in mils) for hard chromium deposits:

Drills	0.05-0.5
Reamers	0.1-0.5
Burnishing bars	0.5-3.0
Drawing plugs, mandrels	1.5-8.0
Drawing dies	0.5-8.0
Gages	0.1-1.5
Pump shafts	0.5-3.0
Rolls, drums	0.25-12.0
Hydraulic rams	0.5-4.0
Printing plates (engraved steel)	0.2-0.5

Nickel Electroplates

COMMONLY USED PLATING BATHS

Watts. The Watts type bath is the most commonly used plating bath and is very flexible with respect to composition, current density and temperature. The bath is used to obtain a decorative matte finish or a bright finish subsequent to polishing or buffing. It is also used to build up worn or mismachined parts that are subject to wear. Relatively thick deposits are used for electroforming and to prevent corrosion of steel pipe and other equipment used for the processing of chemicals, petroleum and foods. The baths are usually grouped into two classifications on the basis of operating pH:

	High pH	Low pH
Nickel sulfate, oz/gal	32	44
Nickel chloride, oz/gal	6	6
Boric acid, oz/gal	4	5
pH	4.5-6.0	1.5-4.5
Temperature, F	115-160	115-140
Current density, amp/sq ft	20-100	25-100

Advantages of the low pH bath (commonly known as the soft nickel bath or general purpose bath) over the high pH bath are: 1) higher current densities (resulting in increased output) can be used without causing deposit peeling or cracking; and 2) improved anode efficiency decreases nickel salt consumption. Disadvantages of the low pH bath are: 1) lower throwing power at low current densities; 2) tendency to pit at some points in the pH range; and 3) lower cathode efficiency.

Chloride-sulfate. This bath produces deposits with modified characteristics of the Watts type and all-chloride baths:

Nickel sulfate, oz/gal	26	pH	1.5
Nickel chloride, oz/gal	23	Temperature, F	115
Boric acid, oz/gal	5.3	Current density, amp/sq ft	25-100

The increased chloride concentration produces a smoother, finer grained, more easily buffed deposit with less tendency to pit than the Watts bath. The bath can also be operated at lower voltages and higher current densities at greater cathode efficiency. Advantages claimed over the all-chloride bath are a more ductile deposit, easier pH control, simpler purification, and compatibility with available organic brighteners.

Hard nickel. This bath is used primarily when a deposit is needed which is tougher and less liable to crack and peel than chromium and where the extreme hardness of chromium is not essential. Deposits possess high resistance to wear and corrosion and are adaptable to conventional machining practices. If a heavy deposit with an extremely hard surface is required, a dual layer of hard nickel followed by chromium can be used.

Nickel sulfate, oz/gal	24	pH	5.6-5.9
Ammonium chloride, oz/gal	3.3	Temperature, F	110-140
Boric acid, oz/gal	4.0	Current density, amp/sq ft	25-50

THICKNESS OF DEPOSITS

Decorative applications: up to 0.5 mil
Corrosive applications: 3 to 15 mils
Applications to improve wear resistance: 0.002 to ¼ in.

PHYSICAL AND MECHANICAL PROPERTIES

Density, lb/cu in	0.322
Specific Gravity	8.9
Melting Point, F	2640
Specific Heat (32-212 F), Btu/lb/°F	0.11
Coef of Thermal Expansion (32-212 F), per °F	7.5×10^{-6}
Ther Cond (32-212 F), Btu/sq ft/hr/°F/in.	470
Electrical Resistivity (68 F), microhm-cm	7.0
Modulus of Elasticity in Tension, psi	30×10^6
Tensile Strength, psi	
Soft Gray Deposits	51,000
Hard Bright Deposits	140-160,000
Elongation (in 2 in.), %	
Soft Deposits	30
Bright Deposits	10
Vickers Hardness	
Soft Deposits	150
Bright Deposits	475-525

RECOMMENDED BASIS METAL PRETREATMENT[a]

Basis Metal	Application: Decorative	Application: Industrial	Sequence of Pretreatment Operations
Aluminum	X	X	Two general classes of pretreatment processes available: 1) application of immersion deposits (such as zincate process); and 2) variations of anodizing (such as phosphoric acid anodizing process)
Brass	X		Degreasing + cathodic and anodic alkaline cleaning + cold water rinse + hydrochloric acid dip + cold rinse
Brass		X	Degreasing + cathodic alkaline cleaning + pumice scrub + cold rinse + nitric acid dip
Cast Iron	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment
Copper	X		Degreasing + cathodic and anodic alkaline cleaning + cold rinse + sodium cyanide dip + cold rinse + cold sulfuric acid dip + cold rinse
Copper		X	Degreasing + cathodic alkaline cleaning + pumice scrub + cold rinse + nitric acid dip + cold rinse
Copper Alloys		X	Degreasing + cathodic alkaline cleaning + pumice scrub + cold rinse + etch in cold solution of nitric-sulfuric-hydrochloric acid + cold rinse + dip in sodium hydroxide and potassium persulfate solution + cold rinse + short dip in 1% (by vol) sulfuric acid solution + cold rinse
Inconel	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + treatment in acid nickel chloride solution
Monel	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment + cold rinse
Nickel (wrought)		X	Degreasing + cathodic alkaline cleaning + pumice scrub + cold rinse + anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment
Nickel (electrolytic)	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + treatment in low pH Watts type or all-chloride nickel bath + cold rinse
Nickel-Iron Alloys	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment
Steels (carbon)	X		Degreasing + cathodic and anodic alkaline cleaning + cold rinse + hydrochloric acid dip + cold rinse
Steels (carbon)		X	Degreasing + cathodic alkaline cleaning + pumice scrub + cold rinse + anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment + cold rinse
Steels (nickel)	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment + cold rinse
Steels (stainless)	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + treatment in acid nickel chloride solution
Steels (tungsten)	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + anodic sulfuric acid treatment + cold rinse + treatment in acid nickel chloride solution (cathodic only)
Tin or Tinplate	X	X	Degreasing + cathodic and anodic alkaline cleaning + cold rinse + cyanide copper plating + cold rinse + acid ammonium citrate solution treatment + cold rinse
Zinc	X	X	Treatment in solvent degreaser or emulsion slush cleaner + soak cleaning + warm water rinse + anodic cleaning + cold water rinse + dip in 2% sulfuric acid solution + cold water rinse + copper plate + cold water rinse

[a] Basis metal surface should be smooth and free of scale and tarnish. Rapid transfer of parts from last pretreatment operation to plating bath is recommended.

USES

Because of their good corrosion resistance and favorable physical and mechanical properties, nickel electrodeposits are used in numerous and diverse applications. Principal among the applications for nickel electrodeposits are: 1) decorative and industrial corrosion resistant coatings in matte, semibright and bright finishes; 2) coatings to build up worn or mismachined parts; 3) electroformed parts; and 4) coatings for nonconductors.

BASIS METALS PLATED

Aluminum and its alloys
Beryllium copper
Brass
Cast iron
Copper and its alloys
Inconel
Magnesium
Monel
Nickel (wrought and electrolytic)
Nickel-iron alloys
Nickel silver
Pewter
Lead-base alloys
Steel (carbon, nickel, tungsten and stainless
Tin and tinplate

Organic Coatings

Type →	Vinyl-Alkyd (approx 1:1 ratio)	Vinyl (100%)	Silicone-Alkyd (approx 1:1 ratio)	Epoxy (100%)
CHEMICAL RESISTANCE				
Exterior and Salt Spray	Excellent	Very good	Excellent	Excellent
Solvents				
Alcohols	Good	Excellent	Fair	Excellent
Gasoline	Excellent	Excellent	Excellent after bake	Excellent
Hydrocarbons	Poor	Good	Poor	Excellent
Esters, Ketones	Poor	Poor	Poor	Fair
Chlorinated Solvents	Poor	Poor	Poor	Excellent
Beverages, Foods	Fair	Excellent	Poor	Excellent
Fruit Juices	Fair	Excellent	Poor	Excellent
Salts (all concentrations)	Good	Excellent	Fair	Excellent
Alkalis—Strong				
Dilute (up to 20%)	Good to 10% at rm temp	Excellent to 180 F	Poor	Excellent
Conc (>20%)	Poor	Excellent to 180 F	Poor	Excellent
Ammonia	Poor	Excellent—fumes, good—immersion	Poor	Poor
Mineral Acids				
Dilute (up to 10%)	Very good	Excellent	Good	Excellent
Medium (10–30%)	Good	Excellent	Poor	Very good
Conc (>30%)	Poor	Good	Poor	Good
Oxidizing Acids				
Dilute (up to 10%)	Poor	Excellent	Poor	Good
Medium (10–30%)	Poor	Very good	Poor	Poor
Conc (>30%)	Poor	Good	Poor	Poor
Organic Acids (acetic, formic, etc.)				
Dilute (up to 10%)	Good	Excellent	Poor	Good
Medium (10–30%)	Fair	Poor	Poor	Fair
Conc. (>30%)	Poor	Poor	Poor	Poor
Organic Acids (oleic, stearic, lactic, etc., all conc)	Excellent	Excellent	Good	Excellent
Phosphoric Acid	Fair	Excellent	Poor	Poor
Water—Salt, Fresh	Excellent	Excellent	Good	Very good
PHYSICAL PROPERTIES				
Sward Rocker Hardness (after 7 days)	26	20	16	36
Flexibility	Very good	Excellent	Good	Excellent
Abrasion Resistance (Taber CS-10 wheel), cycles	2500	>5000	1000	>5000
Max Rec Svc Temp, F	200	180	1000	400
Adhesion to:				
Wood, Masonry	Excellent	Excellent	Excellent	Very good
Ferrous Metals	Very good	Very good over wash coat primer	Very good	Excellent
Nonferrous Metals	Very good over wash coat primer	Very good over wash coat primer	Fair	Excellent
Old Paints	Good	Poor	Excellent	Poor
APPLICATION				
Ease of Application	Dries faster than ordinary paints	Like lacquer	Like ordinary paints	Catalyst addition required
Metal Surface Preparation	Primer	Primer	No primer	No primer
Solvent for Application	Ketone	Ketone	Mineral spirits or turpentine	Ketone
Drying Times				
Touch	15 min	15 min	45 min	45 min
Handle	2 hr	30 min	2 hr	2 hr
Hard	6–8 hr	4-6 hr	12 hr	12 hr
Re-Coat	4–6 hr	4–6 hr	4-6 hr	6–8 hr
Corrosion Resistance	6 hr	24 hr	12 hr	7–10 days
Coverage, sq ft/gal/1-mil coat	300	250	500	450
Cost, ¢/sq ft/1-mil coat	1½	2½	2½	2
Thickness per Coat (avg), mil	1.2	1.0	0.6	1.8

Organic Coatings—concluded

Type ➡	Epoxy-Phenolic (approx 1:1 ratio)	Chlorinated Rubber	Fluorocarbon (air dried)
CHEMICAL RESISTANCE			
Exterior and Salt Spray	Excellent	Very good	Good
Solvents			
Alcohols	Excellent	Fair	Fair
Gasoline	Excellent	Good	Fair
Hydrocarbons	Excellent	Poor	Poor
Esters, Ketones	Excellent	Poor	Poor
Chlorinated Solvents	Excellent	Poor	Poor
Beverages, Foods	Excellent	Fair	Excellent
Fruit Juices	Excellent	Fair	Excellent
Salts (all concentrations)	Excellent	Excellent	Excellent
Alkalis—Strong			
Dilute (up to 20%)	Excellent	Excellent to 10%, good to 20% up to 212 F	Excellent to 212 F
Conc (>20%)	Excellent	Fair to 212 F	Excellent to 212 F
Ammonia	Very good	Very good—fumes, fair —immersion	Excellent
Mineral Acids			
Dilute (up to 10%)	Excellent	Excellent	Excellent
Medium (10-30%)	Excellent	Good	Excellent
Conc (>30%)	Excellent	Poor	Excellent
Oxidizing Acids			
Dilute (up to 10%)	Excellent	Excellent	Excellent
Medium (10–30%)	Very good	Good	Excellent
Conc (> 30%)	Poor	Poor	Excellent
Organic Acids (acetic, formic, etc.)			
Dilute (up to 10%)	Excellent	Good	Excellent
Medium (10–30%)	Excellent	Poor	Excellent
Conc (>30%)	Very good	Poor	Excellent
Organic Acids (oleic, stearic, lactic, etc., all conc)	Excellent	Excellent	Excellent
Phosphoric Acid	Excellent	Good	Excellent
Water—Salt, Fresh	Excellent	Very good	Excellent
PHYSICAL PROPERTIES			
Sward Rocker Hardness (after 7 days)	44	24	20
Flexibility	Excellent	Very good	Excellent
Abrasion Resistance (Taber CS-10 wheel), cycles	>5000	>5000	1000
Max Rec Svc Temp, F	400	250	212
Adhesion to:			
Wood, Masonry	Very good	Excellent	Excellent
Ferrous Metals	Excellent	Very good	Very good over wash coat primer
Nonferrous Metals	Excellent	Very good over wash coat primer	Very good over wash coat primer
Old Paints	Poor	Excellent	Poor
APPLICATION			
Ease of Application	Like ordinary baking enamels	Like ordinary paints	Like lacquer
Metal Surface Preparation	No primer	No primer	Primer
Solvent for Application	Blend of ketone and alcohol	Aromatic hydrocarbon	Proprietary solvent
Drying Times			
Touch	Bake only	45 min	5 min
Handle	10 min at 450 F, or	2 hr	15 min
Hard	30 min at 400 F, or	4–6 hr	12 hr
Re-Coat	60 min at 350 F, or	4–6 hr	12 hr
Corrosion Resistance	120 min at 310 F	24 hr	12 hr
Coverage, sq ft/gal/1-mil coat	450	450	250
Cost, ¢/sq ft/1-mil coat	1¾	1½	15
Thickness per Coat (avg) mil	1.8	1.5	1.0

Porcelain Enamels

COMPOSITION

Porcelain enamel coatings are formulated for specific applications. They consist essentially of oxide color pigments, opacifiers and gases colloidally dispersed in fused silicates. They are smooth, hard and lustrous, and resist temperatures as high as 1000 F (except on aluminum). They may be formulated to provide an attractive, easily cleaned, durable finish; a chemical resistant barrier; or a wear resistant surface.

The enamels generally comprise one, two or three layers. The first layer on ferrous metals is usually a 3 to 4-mil "ground coat" (analogous to an organic primer) containing an oxide of cobalt, nickel or molybdenum that promotes good adhesion with the base metal. Where appearance is not important a ground coat may be used alone; but ordinarily it is followed by one or two 3 to 4-mil top coats, depending on the thickness required to achieve the desired opacity or protection.

Two general types of porcelain enamel frits are most widely used. Titanium types—so called because titanium dioxide is the opacifier—are preferred for white coatings because of their high covering power which makes necessary only a single 3 to 4-mil top coat. These relatively thin coatings (about 7 mils with a ground coat) have good acid resistance; good abrasion resistance; and good resistance to chipping during shearing, bending, punching and other fabricating operations. Titanium coatings can also be used for light or pastel colors, but where deep, bright colors are desired, acid resistant antimony type coatings are used. These coatings do not have the covering power of titanium types and require two 3 to 4-mil top coats for good appearance. They are also less abrasion resistant than titanium types.

Frits for aluminum and aluminized steel contain lead and are softer than conventional enamels. Lead-free frits are undergoing field tests.

BASE METALS

Enameling iron. Ingot iron specially made for enameling. Produced in several grades suitable for various degrees of drawing or spinning. Good resistance to sagging and warping during firing. Produces minimum of surface defects in enamel.

Mild steel. Open hearth rimmed steel sheets such as AISI 1008 and 1010. Available in drawing quality grade. Likely to produce surface defects in enamel. Poor resistance to sagging and warping during firing.

Titanium enameling steel. Basic open hearth steel containing enough titanium to combine with and stabilize the carbon. Better drawing quality than enameling iron but somewhat inferior to the best deep drawn grades of mild steel. Yield strength comparable to that of enameling iron. Excellent sag resistance. Can be coated directly with white covercoat enamels, making possible thin coatings. Expensive and somewhat limited in supply.

Cast iron. Typical satisfactory composition: 2.50 silicon, 0.70 phosphorus, 0.60 manganese, 0.08 sulfur, 3.00 free carbon and 0.40% combined carbon. Must have reasonably dense and uniform structure and be free from porosity, slag inclusions and segregation. Should be capable of developing a fairly smooth surface when sandblasted.

Aluminum. Includes wrought 1100, 3008, 6053 and 6061, and cast 43. Used for light weight, workability and resistance to edge corrosion. Can be cut without spalling after enameling. Requires prior surface treatment.

Aluminized steel. Combines strength, rigidity and sag resistance of steel with much of the workability and corrosion resistance of enameled aluminum. Requires no prior surface treatment.

Stainless steel. Not commercially important at present, but promising because of its corrosion resistance and the fact that, unlike aluminum, stainless enameled on only one side does not require straightening after firing.

APPEARANCE

Color. Strongest, brightest colors are obtained in clear glasses, and some desirable colors such as the cadmium-selenium reds and oranges and the cadmium yellows can be obtained only in clear glasses. Moderately strong to bright colors can be obtained with semi-opaque antimony and zirconium frits.

Light to moderately strong colors are obtained with reduced opacity or "semi-opaque" titanium frits. Most stable colors are ivory-yellow, yellow, yellow-brown and blue-green; however, pink, gray and other popular decorator colors are currently in production even though some, notably pink, require very expensive raw materials. Semi-opaque enamels are applied about 20% thicker than standard white enamels. Weak or light pastel colors can be obtained with opaque titanium frits. Crimson to purple range of colors is still virtually impossible to obtain satisfactorily.

Metallic finishes such as copper, bronze, gold and gunmetal can be produced by some enamelers. Speckled finishes, once limited to white on dark blue or black, are now available in a greater variety of colors and designs. A wide range of luminescent colors that glow in ultraviolet light can be produced.

Precolored frits, once available only in intense blues and blacks, are now available in blue-green and in several lighter colors.

Pattern. Available in wood grain and marble-like patterns, in speckled designs, and in various other novelty patterns.

Texture. Ranges from extremely high gloss to a dull, full matte. Both glossy and matte finishes can be obtained in colors.

Opacity. Varies with color. White enamels usually require reflectance of 70 to 80% for satisfactory hiding power.

THICKNESS

The conventional porcelain enamel coating on steel consists of a ground coat and a cover coat having a total thickness of 7-8 mils. Enamel coatings on heavy castings are sometimes much thicker (up to 25 mils). Thinner coatings can be achieved by using special enamels, special base metals, or special surface treatments prior to enameling. For example, single coats of 3-4 mils are used on aluminum and aluminized steel. Titanium-bearing steel requires only a single coat. Some of the low firing enamels (i.e., enamels fired at temperatures as low as 1250 F) can be applied in a single coat. Promising surface treatments include application of a phosphate coating, and etching or blasting followed by electroless nickel plating.

APPLICATION METHODS

Porcelain enamel coatings are applied by hand spraying, hand dipping, automatic spraying, automatic dipping and flow coating.

Automatic spraying provides more uniform coatings than hand spraying, reducing the amount of enamel needed to insure a specified minimum thickness. Electrostatic spraying reduces overspraying, producing potentially significant materials savings, particularly where expensive colored enamels are used.

Mechanized dipping, relatively new, is more adaptable to complex parts than automatic spraying. Flow coating is particularly advantageous for large cylindrical parts. Flow coated enamels are thinner at the top of the part and are prone to drain streaks.

Firing temperatures of ground coats range from 1600 to 1700 F. Firing temperatures of conventional cover coats on steel range from 1350 to 1500 F. Some of the new low firing enamels mature at temperatures as low as 1250 F. Enamels for aluminum are fired at about 1000 F.

CHEMICAL RESISTANCE

Acid resistance at room temperature. Enamels are rated AA, A, B, C or D, depending on their performance in the standard PEI T-7 or ASTM C 282 test. An enamel surface is exposed to a 10% solution of citric acid for 15 min at 80 F. The enamel is rated according to the appearance of the attacked area and the extent to which it retains a soil. Enamels with an acid resistance rating of A or above are usually specified where acid resistance is required.

Boiling acid resistance. Measured as weight loss of specimen exposed to boiling 6% solution of citric acid for 2½ hr (ASTM C 283).

Weathering resistance. Porcelain enamels that have acid resistance of at least Class B are usually able to withstand weathering for many years without becoming objectionably faded or etched. Enamels of less than Class B acid resistance usually exhibit poor weathering resistance. Certain AA acid resistance enamels containing a cadmium-selenium pigment appear to have poor weathering resistance.

Alkali resistance. Enamels with good alkali resistance are available. No standard test exists, but a test widely used consists of measuring the loss in weight and gloss after exposure to a hot sodium pyrophosphate solution.

PHYSICAL AND MECHANICAL PROPERTIES

Abrasion resistance. Porcelain enamels combine a Mohs hardness of 4 to 6 with an exceptionally smooth surface, resulting in good resistance to scratching and abrasion. Abrasion resistance of a porcelain enamel is determined by abrading a specimen for a given time with an abrasive charge of grit, steel balls and water.

Surface abrasion resistance is an index of enamel's ability to retain its appearance after being subjected to abrasion at or near the surface. Index is percentage of original gloss retained after specimen has been abraded for about 5 min (PEI T-2).

Subsurface abrasion resistance is index of enamel's ability to protect underlying metal from exposure. Index consists of rate of weight loss over three successive 15-min abrasion periods (PEI T-2).

Torsion resistance. Torsion resistance is better in softer enamels and thinner coatings. It is determined by twisting enameled metal angle until enamel fails along apex. Angle of twist at which failure occurs is index of resistance to torsion (PEI T-5).

Adherence. Ability of enamel to protect base metal after it has been exposed to deformation is measured by adherence index. Index is determined by deforming an enameled metal specimen, then measuring relative areas of exposed metal and adhering enamel (PEI T-17, ASTM C 313).

Thermal shock resistance. Porcelain enamels do not normally fail from thermal shock unless they are cooled very rapidly from a high temperature. Coatings quenched with water may crack or spall. Thin coatings stand up much better than thick coatings. A standard test is under consideration by PEI, and a standard test for enameled kitchenware has been adopted by ASTM.

Thermal expansion. Thermal coefficient of expansion of an enamel should be such that from the firing temperature to the temperature of solidification no undue strains are set up between coating and base metal. In general, coefficient of expansion of enamels for flatware should be slightly greater than that of the base metal, and coefficient of enamels for cast iron should be close to that of the casting.

Heat resistance. Most enamels soften at about their firing temperature, but limiting service temperature is considerably lower and ranges from about 600 to 1000 F, depending on the application. In some cases service temperatures are limited by local strains set up as a result of differences in thermal expansion.

Clad and Precoated Metals

Surface ↓	Base Metal		Coating or Cladding		Critical Functions, Properties	Typical Applications
	Metal	Form	How Applied	Thickness, Finish		
Aluminum and Its Alloys						
Aluminum	Steel, low carbon or copper-bearing	Sheet, strip, 0.016–0.112 in.	Hot dipped	0.001 in. on each side (0.50 oz/sq ft)	High heat reflectivity. High temperature oxidation resistance. Forms refractory iron-aluminum alloy at 1000 F. Strong, low cost base	Oven door liners, aircraft fire walls, auto mufflers, broiler parts, baffles for space heaters, toaster inner parts, water heater casings, jet engine parts
Aluminum	Steel (ASTM A 122)	Strand, 7-wire, ⅛–⅝ in.	Hot dipped	0.40–1.00 oz/sq ft (Class A)	Atmosphere resistance. Galvanic protection. Strong base. Longer life than zinc coated steel	Guy wires, span wires, overhead ground wires
Aluminum [a]	Steel, low carbon	Strip, 0.005 in., annealed	Clad by pressing, rolling	10% of thickness on each side	High temperature oxidation resistance. At 1000 F forms gray iron-aluminum alloy that gives 85% black body radiation. Cheaper than carbonized nickel or nickel-clad steel. Conserves nickel	Anode plates for electronic receiving tubes
Aluminum [b]	Steel, low carbon	Same as above	Clad by pressing, rolling	Same as above	Same as above, but suitable for higher ambient temperatures	Anode plates for electronic receiving tubes where close tube spacing makes external temperature too high for aluminum
1100	Aluminum (2024)	Sheet, 0.016–0.250 in., O or T3	Clad by direct rolling or casting, rolling	2–15% of thickness	Atmosphere resistance. Galvanic protection. Strong base	Military and commercial aircraft frames, cooking utensils, hardware
6053	Aluminum (2014)	Sheet, 0.015–0.250 in., O, T4 or T6	Clad by direct rolling or casting, rolling	Same as above	Atmosphere resistance. Galvanic protection. Wear resistance. Workable base	Power shovel bails, aircraft fittings, heavy duty forgings
6053	Aluminum (5056)	Wire, up to ⅜ in. dia	Clad by casting, drawing	Same as above	Same as above	Insect screening
7072	Aluminum (3003 or 3004)	Sheet, 0.015–0.250 in., temper rolled	Clad by direct rolling or casting, rolling	Same as above	Atmosphere resistance. Galvanic protection. Workable, weldable base	Cooking utensils, gasoline and oil tanks, bus and train trim
7072	Aluminum (3003)	Tube, ⅛–11 in. o. d.	Clad by swaging, drawing	2–15% of thickness on inside	Same as above	Heat exchangers for process industries
7072	Aluminum (7075)	Sheet, 0.020–0.188 in., O or T6	Clad by direct rolling or casting, rolling	2–15% of thickness	Atmosphere resistance. Galvanic protection. High strength base	Aircraft structural parts
Copper and Its Alloys						
Brass, Copper	Steel, low carbon	Sheet, strip, 0.008–0.250 in., temper rolled	Electroplated	0.10–0.15 mils on one or both sides. Natural satin or bright. May be striped, crimped, corrugated	Decoration. Atmosphere resistance. Good solderability	Luggage, hardware, costume jewelry, flashlight cases, lamp tubing, chime tubes, cymbals, picture frames, display stands
Brass [c]	Steel, low carbon	Strip, 0.004–0.125 in., temper rolled	Clad by direct rolling	10 or 15% of thickness on one or both sides	Same as above	Cosmetic cases, bed frames, nameplates, gaskets

[a] 1½% silicon. [b] 1½% silicon with 330 nickel on other side. [c] 70–30 or 85–15.

Clad and Precoated Metals—continued

Surface ↓	Base Metal		Coating or Cladding		Critical Functions, Properties	Typical Applications
	Metal	Form	How Applied	Thickness, Finish		
Copper and Its Alloys (continued)						
Brass [d]	Steel, low carbon	Wire, 0.090–0.375 in.	Clad by plating, drawing	½–1 mil (brass only flash)	Decoration. Atmosphere resistance. Cheap, strong base metal. Conserves brass	Curtain rods, indoor television antennas, lamp stands
Brass, Copper	Zinc	Sheet, strip 0.006–0.125 in.	Electroplated	0.10–0.15 mils on one or both sides. Natural, satin or bright. May be striped, crimped, corrugated	Decoration	Moldings, ornaments, trim, badges, buttons
Bronze [e]	Steel, low carbon	Strip, 0.004–0.125 in., temper rolled	Clad by direct rolling	10 or 15% of thickness on one or both sides	Decoration. Atmosphere resistance. Cheap, strong base metal. Conserves copper	Ornamental trim, shell cases
Copper	Steel, carbon	Wire, 0.006–0.500 in. Also ribbon	Clad by plating, drawing	0.25–35% by weight	Electrical conductivity. Atmosphere resistance. Strong base metal. Conserves copper	Lead-in wires for electronic tubes, communication and power lines, lightning rods, fencing, springs, plumbing float racks
Copper	Aluminum (1100 or 5052)	Sheet, strip, 0.004–0.125 in. Also seamless tubing, wire, bus bars	Clad by pressing, rolling	10% of thickness on each side, or 20% on one side. Also 90/10, 70/30, 5/90/5	Thermal, electrical conductivity. Good solderability. Plating base. Lightweight base metal. Conserves copper	Waveguides, variable condenser blades, pots and pans, downspouts, heat transfer fins, jewelry, shims, bushings, terminals
Copper	Beryllium copper (25)	Strip, 0.010–0.030 in., temper rolled	Clad by direct rolling	10–15% of thickness on one side	Electrical conductivity. Base has good spring properties	Current-carrying springs
Copper	Steel, low carbon	Strip, 0.004–0.125 in., temper rolled	Clad by direct rolling	10 or 15% of thickness on one or both sides	Atmosphere resistance. Compressible surface. Thermal conductivity. Good solderability. Cheap, strong base. Conserves copper	Gaskets, automotive radiator tanks, electrical contact "points" and switches, immersion heater base plates
Copper	Steel, high carbon	Strip, 0.012–0.025 in., annealed	Clad by pressing, rolling	5–20% of thickness on one side, or 10–35% on each side	Electrical conductivity. Plating base. Base has good spring properties	Fuse clips, thin-blade or spiral type springs, pen and pencil clips
Copper	Steel, low alloy (with boron)	Wire, 0.003–0.072 in.	Clad by casting, rolling, drawing	10% of radius for "30% conductivity," 12½% for "40% conductivity"	Electrical conductivity. Atmosphere resistance, Plating base. Strong base metal. Conserves copper	Grid support rods for electronic tubes, communication lines, slide fasteners, plated costume jewelry, lawn mower baskets, fencing, ground rods
Copper	Steel, carbon or low alloy	Plate, 3/16–1¼ in. Also heads	Clad by direct rolling	10–20% of thickness on one side	Resistance to corrosion, erosion. Uniform heat transfer. Conserves copper	Chemical process equipment
Cupro-Nickel	Steel, low carbon	Strip, 0.004–0.125 in., temper rolled	Clad by direct rolling	10 or 15% of thickness on one or both sides	Same as above	Chemical process equipment
Phosphor Bronze (C)	Copper	Strip, 0.012–0.025 in., spring temper	Clad by direct rolling or pressing, rolling	25% of thickness on each side. Also 35/30/35	Good spring properties. Base has high electrical conductivity	Flat spring blades for switches and electrical meters, other current carrying springs

[d]Over copper.

[e]90–10.

continued

Clad and Precoated Metals—continued

Surface ↓	Base Metal		Coating or Cladding		Critical Functions, Properties	Typical Applications
	Metal	Form	How Applied	Thickness, Finish		
Chromium						
Chromium [f]	Aluminum, brass, copper, zinc	Sheet, strip, 0.005–0.230 in., temper rolled	Electroplated	0.15–0.25 mils on one or both sides. Natural, satin, or bright. May be striped, crimped, corrugated	Decoration	Toys, reflectors, trim, squeegee plates, etched nameplates, display signs, grills and louvers, miniature letters, auto accessories
Chromium [f]	Steel, low carbon	Sheet, strip, 0.004–0.250 in., temper rolled	Electroplated	Same as above	Decoration, atmosphere resistance	Switchplates, heater parts, mirror backs, display stands, ferrotype plates, toaster shells, chime tubes
Gold and Its Alloys						
Gold [g]	Bronze, nickel silver, nickel, sterling silver	Strip, 0.007–0.120 in. Also tubing, wire	Clad by brazing, rolling	More ("gold-filled") or less ("rolled gold plate") than 1/20 by wt on one or both sides	Decoration. Atmosphere resistance. Relatively low cost base	Jewelry, including watchcases, bracelets, rings, lockets, eyeglass frames
Gold [h]	Copper, brass, nickel, monel	Strip, 0.010–0.030 in., temper rolled	Clad by brazing, rolling	0.5 mils or more	Chemical resistance. Relatively low-cost base	Bursting disks, other chemical process equipment
Lead and Its Alloys						
Lead [i]	Steel, low carbon	Sheet, strip, 0.005–0.125 in.	Electroplated	¼, ½ or 1 mil min on each side (ASTM B 200). Natural or polished	Atmosphere resistance. Good solderability, drawability. Paint base	Telephone cable sheathing, containers
Lead	Copper (ASTM B 101)	Sheet, strip, 0.019–0.028 in.	Plated (type II) or hot dipped (type I)	0.060–0.075 (A), 0.10–0.15 (B) or 0.20–0.25 (C) lb/sq ft on each side	Atmosphere resistance	Roofing, flashing
Lead [j]	Copper, low carbon steel	Tubing, ¾–2⅛ in. o. d.	Clad by extruding or simultaneous drawing	1/16–⅛ in. on outside	Chemical resistance. Low cost. Base has good strength, high thermal conductivity	Heat exchanger coils for chemical process equipment
Lead	Steel, low carbon	Plate, sheet, strip, ½–10 in. Also rod, angles, channels	Clad by casting, pressing	⅛–½ in. (chemical) up to 8–10 in. (radiation) on one side	Chemical resistance. High density. Low cost. Strong base metal	Chemical process equipment; equipment for use with x-rays, radium and nuclear processes
Lead [k]	Steel, low carbon	Sheet, strip, 0.005–0.125 in.	Hot dipped	0.35 oz/sq ft on each side. Natural or polished	Atmosphere resistance. Good solderability, drawability. Paint base. Higher corrosion resistance than terne plate	Ammunition boxes, ducts
Terne [l]	Steel, low carbon	Sheet, 0.019–0.063 in.	Hot dipped	0.16–0.80 mil on each side	Atmosphere resistance. Good solderability, drawability. Excellent paint base. Low cost	Gasoline tanks, caskets, paint and oil containers, door frames

[f] Over nickel.
[g] 10K or more.
[h] 14K or more.
[i] Sometimes over copper
[j] ATSM B 29.
[k] 90–95%.
[l] 75–85% lead.

Clad and Precoated Metals—continued

Surface ↓	Base Metal		Coating or Cladding		Critical Functions, Properties	Typical Applications
	Metal	Form	How Applied	Thickness, Finish		
Nickel and Its Alloys						
Inconel, Monel	Steel, carbon or low alloy	Plate, 3/16 to 1¼ in. (double-clad) or 3½ in. (single-clad). Also heads	Clad by direct rolling	5–25% of thickness on one side, or 5–15% on each side	Resistance to corrosion, erosion. Uniform heat transfer. Low cost base metal. Conserves nickel	Process equipment
Monel	Steel, low carbon	Strip, 0.010–0.030 in. temper rolled	Clad by direct rolling	10–15% of thickness on one or both sides	Same as above	Process and marine equipment
Nickel	Aluminum, brass, copper, zinc	Sheet, strip, 0.005–0.230 in., temper rolled	Electroplated	0.15–0.20 mil on one or both sides. Natural, satin or bright. May be striped, crimped, corrugated	Decoration	Lighting fixtures, nameplates, fryer lids, broiler pan grids, ice bag caps, eraser disks, license plate frames, buttons
Nickel	Copper	Wire, 0.001–0.312 in. Also ribbon	Clad by plating, drawing	0.1–25 mils	High temperature oxidation resistance. Electrical conductivity	Electrical circuits subjected to high temperatures
Nickel [d]	Steel, low carbon	Sheet, strip, 0.004–0.250 in., temper rolled	Electroplated	0.15–0.20 mil on one or both sides. Natural, satin or bright. May be striped, crimped, corrugated	Decoration, atmosphere resistance	Toys, brush ferrules, nameplates, tack beading, paint test panels, broiler trays, fan blades, knives, chocolate molds, flashlights
Nickel	Iron or carbon steel	Wire, 0.006–0.500 in. Also ribbon	Clad by plating, drawing	0.1–25 mils (½–10% by weight)	Atmosphere resistance. High temperature oxidation resistance	Grid support rods, lead-in wires for electronic tubes; typewriter key levers, springs, clothes racks, stapling and stitching wire
A Nickel	Copper	Wire, 0.001–0.500 in. Also ribbon	Clad by swaging, drawing	27–30% by weight	Corrosion resistance. Electrical conductivity	Electrical circuits subjected to corrosive atmospheres
A or L Nickel	Steel, carbon or low alloy	Plate, 3/16 to 1¼ in. (double-clad) or to 4 in. (single-clad). Also heads	Clad by direct rolling	5–30% of thickness on one side or 5–15% on each side	Resistance to corrosion, erosion. Uniform heat transfer. Low cost base metal. Conserves nickel	Process equipment
L Nickel	Brass, low carbon steel	Strip, 0.010–0.030 in., temper rolled	Clad by rolling	10–15% of thickness on one or both sides	Same as above	Process equipment
330 Nickel	Steel, low carbon	Strip, 0.005 in., annealed	Clad by pressing, rolling	10% of thickness on each side. Often carbonized	High temperature oxidation resistance. Black body radiation. Low cost base metal. Conserves nickel	Anode plates for electronic receiving tubes
Platinum and Platinum Group Alloys						
All	Copper, brass, bronze, nickel	Strip, 0.010–0.030 in., temper rolled	Clad by brazing, rolling	1 or more mils on all or part of one or both sides. May be edge-laid, inlaid	Electrical contact properties. High chemical resistance. Low cost base metal	Electrical contacts, slip rings, chemical crucibles
Platinum	Copper, brass, bronze, nickel	Tubing, seamless, up to 1¼ in. o. d. Also wire	Clad by brazing, rolling	0.005–0.007 in.	High chemical resistance. Low cost base metal. Thermal conductivity	Heat exchangers for chemical processes
Platinum	Molybdenum	Wire, 0.003–0.060 in.	Clad by casting, rolling, drawing	Up to 0.001 in. (88% by wt)	High work function (low primary electron emission). Refractory base metal	Grids for vacuum tubes, particularly for use with thoriated cathodes

[d] Over copper.

continued

Clad and Precoated Metals—continued

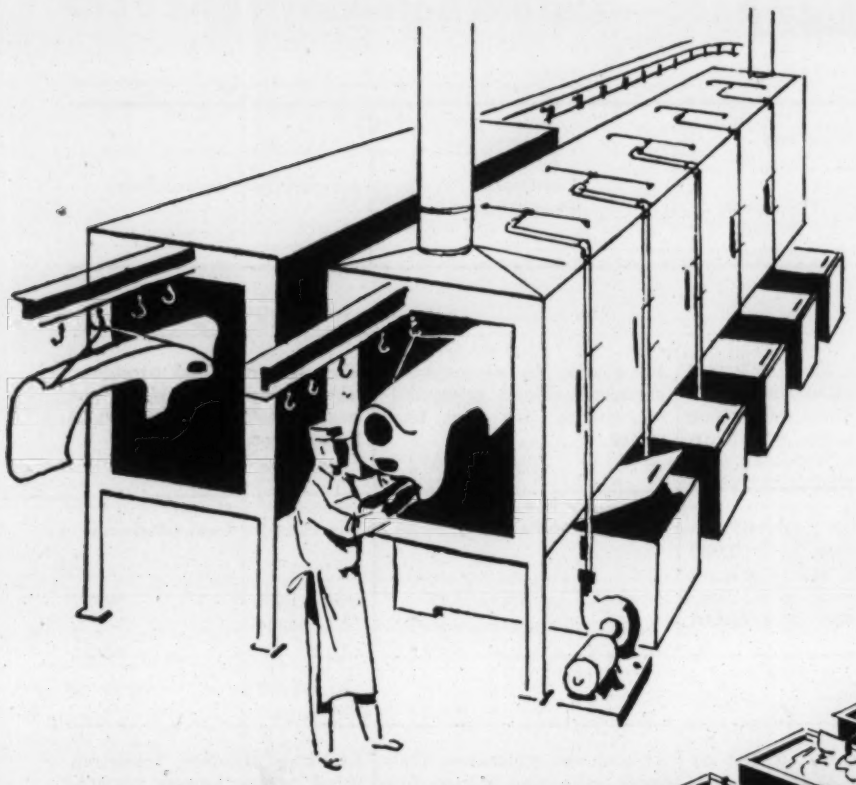
Surface ↓	Base Metal		Coating or Cladding		Critical Functions, Properties	Typical Applications
	Metal	Form	How Applied	Thickness, Finish		
Silver						
Silver	Copper, nickel	Wire, 0.005–0.250 in. Also ribbon	Clad by plating, drawing	0.1–25 mils (½–5% by weight)	Atmosphere resistance. High temperature oxidation resistance. Electrical conductivity. Low cost base	High temperature coils, high frequency conductors, braiding for radar cables, strings for musical instruments
Silver	Aluminum (1100, 5052)	Strip, 0.010–0.062 in.	Clad by pressing, rolling	10% of thickness on each side, or 20% on one side. Also 90/10, 70/30, 5/90/5	Electrical contact properties. Electrical conductivity. Lightweight, low cost base. Decoration	Conductors, contacts in aircraft electrical equipment; costume jewelry
Silver	Aluminum, brass	Tubing, seamless rectangular	Clad by pressing, rolling	0.005 in. on inside	Electronic transmission characteristics. Low cost base	Waveguides for electronic transmission lines
Silver	Beryllium, copper (25)	Strip, 0.010–0.015 in.	Clad by pressing, rolling	15% of thickness on all or part of one or both sides	Electrical contact properties. Electrical conductivity. Base has good spring properties, fatigue life	Contact arms for buzzer circuits, other current-carrying springs
Silver	Copper, brass	Strip, 0.010–0.020 in., temper rolled	Clad by brazing, rolling	1 or more mils on part or all of one or both sides. May be edge-laid, inlaid	Electrical contact properties. Low cost base metal	Electrical contacts, slip rings, flexible waveguides
Silver	Invar	Strip, 0.006–0.008 in., temper rolled	Clad by brazing, rolling	0.2–0.3 mil	Good electrical contact properties. Low thermal coefficient of linear expansion	Television antenna connectors
Silver	Monel, nickel	Strip, 0.008–0.020 in., temper rolled	Clad by brazing, rolling	1 or more mils on part or all of one or both sides. May be edge-laid, inlaid	Electrical contact properties. Resistance to corrosion, wear. Low cost base metal	Electrical contacts subject to corrosive conditions or excessive wear
Silver	Phosphor bronze (A, C, D)	Strip, 0.006–0.040 in., spring temper	Clad by brazing, rolling	Same as above	Electrical contact properties. Electrical conductivity. Base has good spring properties	Electrical contact springs
Stainless Steel						
Austenitic [m]	Copper	Strip, 0.010–0.020 in., annealed	Clad by pressing, rolling	25% of thickness on one or both sides	Resistance to corrosion, erosion. Thermal conductivity. Uniform heat transfer. Workable base metal	Heat exchangers for chemical processes
Ferritic [n]	Copper	Strip, 0.025–0.050 in.	Clad by pressing or brazing, plus rolling	20% of thickness on one or both sides	Corrosion resistance. Thermal conductivity. Uniform heat transfer. Workable base metal. Decoration	Pots and pans
Stainless	Steel, carbon or low alloy	Plate, 3/16 to 1¼ in. (double-clad) or to 4 in. (single-clad). Also heads	Clad by direct rolling	Up to 30% of thickness on one side or 15% on each side	Resistance to corrosion, erosion. Workable low cost base metal	Process equipment
Stainless	Steel, low carbon	Sheet, plate, 0.050–0.250 in., annealed. May be polished	Clad by casting, rolling	20% of thickness on one side	Same as above. Decoration	Process equipment, architectural paneling, auto bumpers, grills and trim, cooking utensils, food display cases, hospital sterilizers
Ferritic [n]	Steel, low carbon	Strip, 0.015–0.095 in., temper rolled	Clad by direct rolling	15% on one or both sides	Corrosion resistance. Decoration. Workable, low cost base metal	Cooking utensils, auto bumpers, grills and trim

[m]304, 310 [n]430.

Clad and Precoated Metals—concluded

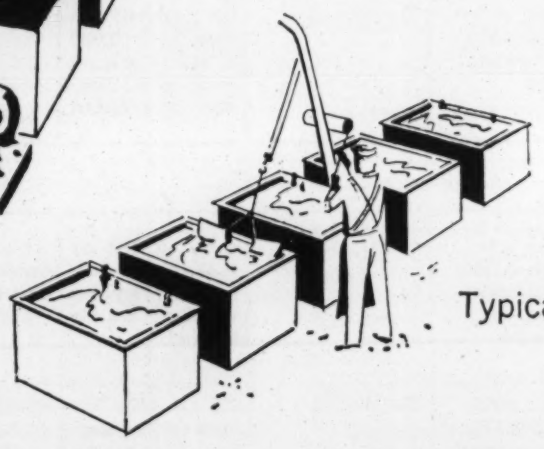
Surface ⬇	Base Metal		Coating or Cladding		Critical Functions, Properties	Typical Applications
	Metal	Form	How Applied	Thickness, Finish		
Tin						
Tin	Steel, low carbon	Sheet, strip, 0.008–0.015 in., temper rolled	Electroplated	0.013–0.053 mil on each side. Also 0.013 mil on one side, 0.053 on other. May be chromate treated	Resistance to atmosphere, chemicals. Good solderability. Strong, low cost base metal	Tin cans for food products, kitchenware, bearings (as base for babbitting), parts to be soldered
Tin	Steel, low carbon	Sheet, strip, 0.005–0.125 in., temper rolled	Hot dipped	0.8-2.0 mils ("common") or 0.080 ("std") mil on each side. Natural or polished	Same as above	Tin cans for food products
Zinc						
Zinc	Steel, low carbon	Sheet, strip, 0.005–0.125 in., temper rolled. Also flat wire	Electroplated	0.01, 0.084 or 0.17 mil on each side. May be phosphate treated	Atmosphere resistance. Galvanic protection. Strong, low cost base metal	Lighting fixtures, venetian blind heads, screen frames, refrigerator parts, sliding door tracks, spools and reels, oil cans, signs, auto window channels
Zinc	Steel, low carbon	Sheet, strip, 0.012–0.172 in., annealed	Hot dipped	0.8-2.0 mils on each side. May be chromate treated	Same as above	Roofing and siding, agricultural equipment, refrigerator and air conditioner parts, auto mufflers
Zinc	Steel, carbon or low alloy (ASTM A 53)	Tubing, ½–1 in. Pipe, ½–12 in. Also conduit	Hot dipped	0.002 in. or more on each side	Same as above	Water pipe. Electrical and hot air conduits
Zinc	Steel, low carbon	Wire, 0.016–0.500 in.	Hot dipped	0.1–1.0 mil	Same as above	Fencing
Organic Coatings						
Alkyd Baked Enamel	Low carbon steel, aluminum	Strip, 0.005–0.050 in., phosphate coated	Painted	½–1 mil on each side. All colors. Low or high formability types	Decoration, atmosphere resistance	Venetian blind slats, curtain rod brackets, calendar frames, auto dashboards, lighting fixture moldings, awnings
Cellulose Lacquer	Steel, low carbon	Strip, 0.005–0.050 in. May be precoated with copper, brass, nickel or zinc; also phosphate coated	Painted	½–1 mil on one or both sides. Clear, all colors	Same as above	Toys, novelties, display frames, premium items, brackets, auto moldings and trim
All	Steel (incl electrogalvanized, tinplate), aluminum, brass, zinc	Strip, 0.006–0.040 in.	Painted	0.1–2.0 mils on one or both sides. Clear, all colors	Same as above	Toys, buttons, buckles, clips, reflectors, picture frames, eraser shields, bottle caps, movie reels, addressograph plates, ashtrays
Polyvinyl Chloride	Steel, aluminum, magnesium	Sheet, strip, plate, 0.010–0.250 in.	Clad by adhesive bonding with heat and/or pressure	0.008–0.030 in. on one or both sides. All colors, special textures	Decoration. Resistance to atmosphere, chemicals. Abrasion resistance. Formability. Low cost base metal	Business machine housings, auto instrument panels, television cabinets, air conditioner housings and drip pans; acid resistant tanks, ducts and fume hoods
Vinyl Lacquer or Enamel	Low carbon steel, aluminum, brass, zinc	Strip, 0.005–0.050 in. Phosphate coated	Painted	0.4–1.0 mil on one or both sides. All colors	Decoration. Atmosphere resistance. Formability	Bottle caps, lipstick cases, garden tools, toys, battery caps, wall tile, eyelets, flashlight parts

ACP Chemicals and Processes improve paint adhesion, provide decorative finishes



Typical power spray system

ACP produces the chemicals for treating most metals—to clean them, to prepare them for further processing, to improve corrosion resistance and paint adhesion. It has the experience and the personnel to apply these chemicals economically and effectively, too. Here are just a few of the many products and processes ACP offers:



Typical immersion system

ACP GRANODINE®—a phosphate coating process for steel which provides an excellent base for paint and greatly improves the corrosion resistance of the paint system.

ACP ALODINE®—an amorphous coating process for aluminum which protects both painted and unpainted metal and anchors the paint finish.

ACP PERMADINE®—a zinc phosphate coating chemical which forms a heavy oil-adsorptive crystalline coating on steel. This coating bonds paint or readily absorbs such rust inhibiting oils as ACP Granoleum.®

ACP DURIDINE®—a dual-action chemical which cleans and phosphate coats steel simultaneously. It carries off harmful surface dirt, oil and grease. It forms a coating which inhibits corrosion and provides an excellent base for the paint finish.

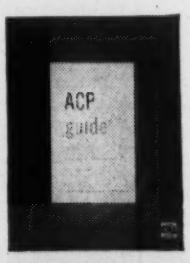
ACP DEOXIDINE®—a phosphoric acid metal cleaner which removes rust and organic soils, destroys rusters, prepares steel, aluminum, brass, copper and other metals for painting.

ACP METAL CLEANERS—Ridoline,® alkaline metal cleaner, and Ridosol,® solvent-detergent metal cleaner—remove metal preservatives and metalworking lubricants from metals in process.

ACP THERMOIL-GRANODINE®—a manganese iron phosphate crystalline coating chemical which improves the wear-resistant and antigalling characteristics of machined reciprocating ferrous elements. The coating, when oiled or painted, also inhibits corrosion.

ACP ARCHITECTURAL ALODINE® PROCESS forms a chemical coating on aluminum which becomes an integral part of the metal, inhibits corrosion, and provides an attractive and lasting color finish. It also reduces glare, is easy and economical to apply.

Write for the "ACP GUIDE to the chemical treatment of metals."



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DATA
SECTION

Forms and Shapes

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Design Features of Metal Forms

Form ↓	Choice of Materials	Complexity of Part	Maximum Size	Minimum Size
Sand Castings	Wide—ferrous and nonferrous metals	Considerable—holes, bosses, locating pads	Great—largest forms made are sand castings	⅛ in. is smallest practicable section
Shell Mold Castings	Wide—same as above excepting low carbon steels	Moderate—limited by mold removal problem	<60 in. square. Best for smaller parts	1/16-in. sections
Permanent Mold Castings	Restricted—brass, bronze, aluminum, some gray iron	Limited—restricted by use of rigid molds	Moderate—50 lb is practical limit in aluminum	1-oz. sections as thin as 0.1 in.
Plaster Mold Castings	Narrow—brass, bronze, aluminum	Considerable—mold destroyed in removal	Moderate—up to 15 lb in most materials	Small—1/32-in. sections possible
Investment Castings	Wide—includes materials hard to forge or machine	Considerable	Moderate—best for parts under 2 lb	Small—sections down to 0.030 in.
Die Castings	Narrow—zinc, aluminum, brass, magnesium	Considerable—though costly dies might be required	Large—up to 75 lb in aluminum, 200 lb in zinc	Sections as small as 0.025 in.
Drop Forgings	Medium—many ferrous, nonferrous alloys	Moderate—limited by die restrictions	Large	Small as fraction of an ounce
Press Forgings	Medium—best for nonferrous alloys	Limited—but greater than drop forgings	Moderate—25-30 lb a practical maximum	Smaller than drop forgings
Upset Forgings	Medium—many ferrous, nonferrous alloys	Limited to cylindrical shapes	Medium—9-in. bar about largest	Moderate—not comparable to casting
Cold Headed Parts	Narrow—confined to steel, highly ductile alloys	Limited—less flexibility than forgings	Small—7 in. by ½ in. dia usual maximum	Small—⅛-in. dia parts can be made
Extrusions	Restricted—light metals, some steels, copper, titanium	Limited—can be complex in cross section only	Medium—8 to 10 in. max dia	Small—0.050-in. sections in aluminum and magnesium
Impact Extrusions	Narrow—aluminum, magnesium, some steel	Limited—must be concentric	Small—6 in. dia in soft alloy, 4 in. in hard	Moderate—¾ in. dia smallest
Roll Formed Shapes	Narrow—cold rolled steel, some aluminum and stainless steel	Restricted to thin and uniform cross sections	Large	Sections from 0.125 in. up
Stamped and Press Formed Parts	Wide—all workable metals	Limited—many design restrictions	Large	Small—sections as thin as 0.003 in. possible
Metal Powder Parts	Moderate—iron, steels, nickel, brass, nickel alloys, refractory metals	Limited—powders flow poorly, do not transmit pressure	Small—parts less than 4 in. square best	Small—<1/16 in. dia possible
Spinnings	Wide—many sheet metals	Limited—cylindrical or concentric shapes	Large—up to several feet in dia	Moderate—¼ in. dia in gages less than 0.040 in.
Screw Machine Parts	Wide—best suited to highly machinable metals	Moderate—limited to rotational shapes	Medium—up to 6 in. long, 2½ in. dia	Small—<1/16 in dia
Electroformed Parts	Narrow—iron, copper, nickel, silver	Great—extreme complexity possible	Limited—½-in. sections can be built up	Small—0.005 in. or less
Tubing	Wide—any ductile metal available in tubular form	Limited by sectional shapes of tubing	Usually 4 to 6 in. o.d.	Moderate—¼ in. o.d.
Welded and Brazed Parts	Wide—dissimilar metals can be joined	Great—extremely complex shapes	Unlimited	Moderate

Mechanical Properties	Precision, Tolerances	Special Structural Characteristics	Surface Smoothness	Surface Detail	Remarks
Fair to high depending upon metal cast	±1/16–1/32 in./in., closer at extra cost	Good bearing structure	Poor	Poor	Usually require some machining before use
Good—little porosity, few gas inclusions	±0.003–0.005 in./in.	High quality for cast metals	Good	Good	Considered best of low cost castings
Fair—good in centrifugal castings	±0.01–0.05 in.	—	Good	Good	Large quantities allow production economies
Fair	±0.010–0.005 in.	—	Good	Good	Little finishing required
Good	±0.005 in./in. common	—	Excellent	Excellent	Best for parts too complicated for other casting methods
Fair to good	±0.001 in./in.	Special properties can be obtained through use of inserts	Good	Good	Most economical where applicable
High	±0.010–0.030 in. without joining	Grain flow provides toughness	Fair	Fair	Used where high strength is required
High	Medium—better than drop forgings	Hot working gives structural advantages	Fair	Fair	Closer tolerances and greater complexity than drop forgings
High	Medium—compare to press forgings	Grain flow provides toughness	Medium	Medium	Best suited to small parts
High	±0.010 in. common, ±0.002 in. possible	Tough structure	High	Fair	High production rates
Good	±0.005–0.020 in. common	Grain flow improves properties	Good	Only as part of contour	Sometimes used as blanks for other processes
High—metal cold worked	±0.001 in. common	Grain flow improves properties	Good	Good	Can eliminate machining
Good	±0.002–0.015 in.	Cold work improves properties	Good	None	Requires large quantities
Fair to high	Good—to ±0.001 in. common	—	High	Fair	Usually low cost when quantities are sufficient
Fair to good	High—±0.001–0.005 in. common	Porosity can be controlled and complex materials formed	Fair	Fair	Can use materials not formable by other processes
Good	Fair—±0.015–0.060 in. common; better at added cost	Grain flow, cold work improve properties	Good	None	Good for large pieces or short runs
High	±0.001–0.005 in. possible	—	Excellent	Good	High production rates, low cost
Fair—lower than wrought	High—±0.002–0.0002 in. common	Extremely dense structure; laminates possible	Excellent	Excellent	Best when complexity and accuracy essential
Good—cold working improves properties	Good—depends on quality of tubing	Grain flow improves properties	Good	None	Good means of reducing costs
Variable—depends upon components	Medium—not highly precise	Can combine parts with special properties	Depends on components	None	Often needed to meet design requirements

Castings

GENERAL

Sand castings. These castings are usually the first type considered. A major advantage is their availability in almost limitless shapes and in extreme complexity. Sand castings can be extremely large, but there is a practical limit to their minimum size. The process is not recommended for thin-section castings.

When moderate quantities of a part are required, sand castings can be relatively inexpensive, despite the hand labor required. Practically any metal can be used, with the exception of the newer metals which react with air while in the molten state. For precision parts, sand castings are usually restricted to the light alloys and certain bronzes.

Precision sand castings. Higher accuracy in sand castings is attributable to foundry techniques and closer control over the variables rather than a change in process. Carefully constructed baked sand cores are used when this accuracy is specified, whereas normal green sand molds are used elsewhere.

Most precision sand castings are formed of aluminum and magnesium alloys and the phosphor and tin-bearing bronzes. The as-cast mechanical properties of these castings are approximately the same as those found in conventional sand castings.

Shell mold castings. These castings are formed of any alloy that can be cast in sand, though some casting alloys may be more difficult than others. The low carbon steels tend to have surface defects. Sweating of tin and lead in brasses and bronzes containing a high percentage of these alloying elements has caused problems. The reactivity of magnesium with oxygen and silica sand must be countered with inhibitors or mold washes.

Mechanical properties are comparable to, or better than, those of sand castings. Closer control can be

GENERAL CHARACTERISTICS OF CASTINGS

Type ↓	Cost				Time[c]	Size			As-Cast Finish, rms[e]
	Labor	Equipment[a]	Material	Typical Pouring Rate, per hr[b]		Range	Avg, lb[d]	Min Section Thk, in.	
Sand	High	Die low, tooling high, pattern ¼ of die	Low	25	3–15 days	<1 oz to >200 tons	Few ounces to several tons	Special—1/16, small—3/32–⅛, large—3/16–¼	Requires grinding, polishing, buffing
Precision Sand	Medium high	Low	High	300 per month	4–6 weeks	Max size not known. Present —<1 lb weight to 6 ft length	1–4	0.050	75–80
Permanent Mold	Medium	High	Nonferrous—high, gray iron—low	30	6–12 weeks	1 oz to 600 lb	1–10	0.090	100–125
Plaster Mold	Medium high	Low	High	4–5	4–6 weeks	<1 oz to >100 lb	3–5	0.040–0.060	50
Investment	High	Varies with quality of pattern die necessary	Wide range	Generally low; higher with plastics pattern	4–6 weeks	<1 oz to 25 lb —wax or plastics; >100 lb—frozen mercury	Up to 1	0.030	60—wax and plastics; 40—mercury
Die	Low	High	High	75–150 aluminum, magnesium, copper-base; 300–350 zinc	8–14 weeks	<1 oz to 75 lb aluminum; <1 oz to 200 lb zinc	½–1	0.050	50

[a]Dies, patterns and/or machines.
[b]These figures are general for one set of equipment. Actual rate of casting production depends on number of cavities per mold.
[c]From complete design to production. [d]Average size of competitive castings. [e]Finish obtainable in limited areas.

exercised. Since the shell mold is baked dry, the lack of moisture slightly increases the insulating effect of the mold; the resulting slower cooling of the metal produces better uniformity of structure. The high permeability of shell molds minimizes porosity and voids in the solidified metal by allowing air and gases generated during pouring to escape through the shell.

Permanent mold castings. Parts must be of relatively simple design, but some complexity is possible by using sand cores with steel molds (semipermanent molding). Because of the relatively low temperature limit of the mold material, the process is limited to the lower melting alloys. Aluminum alloys are the most commonly cast. Copper-base alloys, magnesium and, more recently, gray iron are also cast in permanent molds.

Permanent mold castings are usually dense and fine-grained, and can be made with better surfaces and closer tolerances than sand castings. Molds may be preheated to the 700-800 F range to achieve high control. Tolerances must be wider than for die castings, shell mold castings and plaster mold castings.

Plaster mold castings. These castings are noted for their fine finishes which reflect the smoothness of the plaster in which they are cast. The insulating quality of the mold causes a slower cooling rate which results in a reduction of tensile strength and elongation. Although plaster mold castings are used for some high production parts, they are usually considered for small to medium-sized lots. Molding costs are relatively high, but these costs are usually recovered because of the minimum of machining.

Because of the temperature limitations of the mold material, this method is restricted to casting alloys with a melting point below 2000 F. These include aluminum, magnesium, and some of the copper-base alloys, such as yellow brass, silicon bronze, beryllium bronze, aluminum bronze and manganese bronze. Some foundries restrict lead content to 1.5% because of the reactivity of lead with plaster; others claim to have cast 50% lead alloys without difficulty. Alloys containing silicon lend themselves to finer detail with better surface finish. When casting magnesium, special plaster compositions and handling techniques are required, as well as more ample feeding facilities in the mold.

Investment castings. These parts are formed using a pattern molded in wax, plastic, or frozen mercury. Each pattern type has characteristics that make it more suitable for certain parts. Wax permits the greatest flexibility of design and is the least costly. Plastics permit more rapid production of patterns and also allow a surplus of patterns to be stored for future use. Frozen mercury allows larger sizes to be cast and requires only a thin ceramic shell which, in turn, results in better metal quality. In general, investment cast parts offer dimensional tolerances superior to those of other castings, can be made in shapes too complex for metal powder parts, and can be made of metals with melting points too high for die casting. Mechanical properties are generally high.

Of the six types of close tolerance castings (i.e., excluding sand castings), investment castings are matched only by shell moldings in the range of castable alloys available. These alloys include high melting ferrous alloys, copper alloys, special high temperature nonferrous alloys, and all castable aluminum and magnesium alloys. Though the same

MACHINE FINISH ALLOWANCES

Metal ⬇	Pattern Size, in.	Bore, in.	Finish, in.
Cast Iron	Up to 12	1/8	3/32
	13 to 24	3/16	1/8
	25 to 42	1/4	3/16
	43 to 60	5/16	1/4
	61 to 80	3/8	5/16
	81 to 120	7/16	3/8
	Over 120	g	g
Malleable Iron[a, b, c, d]	Up to 6	1/16	1/16
	6 to 9	3/32	1/16
	9 to 12	3/32	3/32
	12 to 24	5/32	1/8
	24 to 35	3/16	3/16
	Over 36	g	g
Steel[e]	Up to 12	3/16	1/8
	13 to 24	1/4	3/16
	25 to 42	5/16	5/16
	43 to 60	3/8	3/8
	61 to 80	1/2	7/16
	81 to 120	5/8	1/2
	Over 120	g	g
Brass, Bronze, Aluminum[f]	Up to 12	3/32	1/16
	13 to 24	3/16	1/8
	25 to 36	3/16	5/32
	Over 36	g	g

[a] When castings are constructed so that they warp more than the average amount, the allowances given should be increased.
[b] Disk grinding—only sufficient finish required to take care of draft and possible warpage.
[c] Coin pressing—practically no finish allowance required.
[d] For small parts, an allowance of 1/32–1/16 in. is satisfactory. Larger parts require a slightly greater allowance.
[e] Allowance ranges from 1/8 to 1 in. Values given for finish are normal for ordinary finishes on the drag side. For finished surfaces on the cope side, it is often necessary to double the allowance.
[f] For small or medium-sized nonferrous castings, 1/8 in. is a customary allowance, with correspondingly larger allowances on larger castings.
[g] Special instructions.

continued

Castings—concluded

general degree of accuracy is obtainable with all alloys, it is easier to obtain with the nonferrous alloys because of their higher fluidity and lower melting points.

Die castings. Only nonferrous alloys are suitable for die castings. The range of these alloys is adequate for most needs but more limited than for sand castings. Alloys used, in order of tonnage, are: zinc, aluminum, copper, magnesium, lead and tin. They can be grouped in low and high melting classes according to melting point:

Low melting alloys

Zinc	727 F
Lead	484 F
Tin	417 F

High melting alloys

Aluminum	1115 F
Magnesium	1110 F
Copper	1600 F

The high melting group are usually cast in cold chamber or air injection machines; the low melting alloys in plunger machines. Of all casting processes, die casting is by far the best suited to high production of quality parts. As in permanent mold casting, an advantage is derived from the high thermal conductivity of the steel used in the die. The resultant chilling effect promotes fine grained metallurgical structure. Though die castings are subject to varying degrees of porosity, proper engineering of the casting and die may confine it to noncritical areas.

DESIGN FACTORS

Draft allowances. Draft allowance is normally at least ½ in. per ft., although it often ranges from ¼ to ⅜ in. per ft. It is seldom less than 1 deg and ⅛ in. per ft. In sand and plaster mold casting, the mold is destroyed after the casting is made; therefore no draft is required. Investment casting requires no draft, though ½ to 1 deg can be specified if single parting, noncored dies are designed. Frozen mercury, wax and plastics patterns require no draft, but ½ deg is used with Kirksite dies.

Permanent mold—A minimum of 2 deg on each side is usually provided, though the range is 0 to 3 deg. In recesses, 2 deg on each side is a minimum with 5 deg desirable. The following figures (in. per in. of depth on one side) are fairly standard: magnesium—0.015, aluminum—0.015, bronze—0.020.

Shell mold—Draft angles are not as critical as for permanent mold castings. From ¼ to ½ deg is

DIMENSIONAL TOLERANCES •

Sand Castings

Gray Iron	1/32–1/16
Malleable Iron	3/32
Steel	5/32
Aluminum Alloys	5/64
Magnesium Alloys	11/64
Brass	3/32
Bronze	1/8

(Zinc, tin, lead not cast)

Shell Mold Castings

Ferrous	0.001–0.003 in./in. possible. Commercially 0.010 to 0.015 are held on dimensions within mold half. Across parting line: 0.020–0.030
Magnesium, Others	Same as ferrous

(Zinc, tin, lead not cast)

Permanent Mold Castings

Aluminum	0.015 for first inch; then 0.002 in./in. Common total: 0.010–0.050
Magnesium, Gray Iron, Others	Same as aluminum or slightly wider

(Steel, tin not cast)

Plaster Mold Castings

Brass, Bronze	0.005 for first inch; then 0.001 in./in. Common total: 0.005 to 0.010
Aluminum, Others	Same as brass and bronze

(Ferrous, zinc, tin, lead, copper not cast)

Investment Castings

Copper	0.002–0.005 in./in.
Stainless Steel	0.004–0.008 in./in.
Others	0.003–0.006 in./in.

(Iron, some steels, zinc, tin, lead not cast)

Die Castings

Zinc	0.0025 for less than 1 in. 0.001 in./in. for dimensions greater than 1 in.
Aluminum, Magnesium	0.003 for less than 1 in. 0.001–0.002 in./in. for dimensions greater than 1 in.
Others	0.005 for less than 1 in. 0.003 in./in. for dimensions greater than 1 in.

(Ferrous not cast)

•Tolerances are for usual commercial practice, stated for guidance only. In most cases closer tolerances can be held at increased cost. Tolerances are over-all unless stated as in. per in. All values are ± tolerances.

usually sufficient for shell mold castings.

Die—In general, a minimum of 2 deg per side is usually provided. The following draft tolerances (in.) are usually provided:

Magnesium	0.010[a]
Aluminum	0.010-0.015
Zinc	0.005-0.007
Brass, bronze	0.015-0.020
Tin, lead	0.015

[a] In. per in. of depth, one side.

Shrinkage allowances. The following allowances (in. per ft) are usually provided:

Cast iron	1/8
Malleable iron	1/8
Steel	1/4
Aluminum	5/32
Brass	3/16

DESIGN RULES

1. Stress concentration is always a vital consideration. A larger amount of metal will have greater shrinkage and put an adjoining thin section under tension which may result in cracking. The design should incorporate fillets when there is a change of section thickness or to avoid sharp, interior corners. In addition to lowering stress concentration, fillets help achieve even cooling and shrinkage.

2. Continuous, intersecting ribs may cause trouble. Staggering the ribs will help prevent the build-up of high stresses.

3. Avoid large, flat areas with little or no support.

4. The parting line, particularly in die castings, is preferably located at the corner of the casting. Lines of demarcation remaining after flash removal will not be nearly as visible.

MINIMUM SECTION THICKNESS (In.)[a]

Sand Castings	
Gray Iron[a]	1/8–3/16
White Iron	1/8–3/16
Malleable Iron	1/8–3/16
Steel	3/16–1/4
Aluminum	1/8–3/16
Magnesium	3/16–1/4
Brass, Bronze	3/32–1/8
Shell Mold Castings[b]	
Ferrous	1/16–1/8
Magnesium, Others	1/16–1/8
Permanent Mold Castings	
Aluminum	
< 3 In.	3/32–1/8
3 to 6 In.	5/32
>6 In.	3/16
Gray Iron, Others	
<3 In.	3/32–1/8
3 to 6 In.	5/32
>6 In.	3/16
Plaster Mold Castings	
Brass, Bronze	
2 Sq In.	0.040
4 to 6 Sq In.	0.063
<30 Sq In.	0.093
Aluminum, Others	
2 Sq In.	0.040
4 to 6 Sq In.	0.063
<30 Sq In.	0.093
Investment Castings[b]	
Copper	0.030
Stainless Steel	0.050
Others	0.030
Die Castings	
Zinc	
Small	0.020–0.030
Large	0.050
Aluminum	0.035
Magnesium	0.050
Aluminum Alloy	
Small	0.045–0.055
Large	0.080
Magnesium Alloy	
Small	0.050–0.060
Large	0.080
Copper	
Small	0.06
Large	0.10
Brass, Bronze	0.050
Tin	
Small	0.030
Large	0.060
Lead	
Small	0.040
Large	0.070

[a] Usual minimum for various classes of gray iron is: class 20, 1/8; class 25, 1/8; class 30, 1/4; class 35, 3/8; class 40, 1/2; class 50, 1/2; class 60, 3/4.
[b] Avoid section differences where max : min ratio is more than 5 : 1.

Extrusions

GENERAL

Extruding is used increasingly as a means of making small parts of uniform cross section that might otherwise be made only through extensive machining. Long pieces of the desired cross section are extruded, then cut to desired lengths and subjected to any further operations that may be required.

Advantages. Extruded shapes are not considered to be highly precise as far as dimensional tolerances are concerned, but they do have the advantage of permitting the metal to be placed where it is most needed to attain desired strength and design characteristics. Relatively complex shapes can be extruded. Sharp corners and reentrant angles are readily obtainable. When precision is a requirement, final dimensions are achieved through machining. Extruding is sometimes used to make blanks for other processes, e.g., forging.

Limitations. Sizes are limited because of the excessive size of the presses required to extrude large sections, and because large shapes are likely to bend and distort excessively under their own weight and require expensive straightening operations. Any openings must be in the direction of the extruding action and uniform throughout the entire length of the extrusion.

Materials. Although in the past most extruded shapes have been made from aluminum, magnesium and copper alloys, the process has recently been expanded to include many types of steels. Steels and other high melting alloys are easy to extrude, but they are hard on die materials and require lubricants with special qualities. Titanium, lead, tin and zinc alloys are also extruded. For best results the ratio of billet size to finished extrusion should be large. When large ratios are used, the resulting extrusions are dense, homogeneous and free of porosity, and the metal properties compare favorably with those attained in forging. Ratios usually range from 20:1 to 40:1.

Speed of output. Rate of output of extruded shapes can affect cost, particularly if large quantities are required. Speeds range from 1½ to 700 fpm., depending on the basic material, the particular alloy and the shape being extruded. Magnesium is extruded at speeds of 4 to 100 fpm., aluminum somewhat faster, and copper alloys a little slower. Highest speeds are attained with nickel alloys and steels.

Applications. Conditions under which extruded shapes might be chosen are:

1. When a more efficient disposal of metal is desirable than is obtainable with rolled shapes or other metal forms.
2. Where several parts are now joined to provide a small assembly.
3. Where shapes are required that could not be obtained without difficult machining.
4. Where short pieces of an extrusion could replace small castings or forgings.

DESIGN FACTORS

Tolerances. Tolerances on extruded metal parts are held on such factors as straightness, flatness, twist, section thickness, angles, contours, and corner and fillet radii.

Flatness—On a 6-in. width, tolerance would be ±0.024 in., or about 0.004 in. per in. of width.

Straightness—On a 5-ft length, a 1/16-in. deviation from a straight line is normal. This deviation increases to ⅜ in. at 30 ft.

Cross section—Typical are tolerances ranging from ±0.006 in. on thicknesses of less than 0.125 in. up to ±0.080 in. on thicknesses or widths of 14-15 in.

Cut ends—Permissible deviation from the square is 1 deg.

Curved surfaces—Allowable deviation from a specified contour is 0.005 in. or 0.004 in. per in. of chord length, whichever is greater. This tolerance does not apply to an arc of more than 90 deg.

Section thickness. Thickness of sections usually ranges from 0.050 in. up to several inches. Ratios of thickness to width vary with materials used and are standardized for aluminum and magnesium extrusions. Aluminum alloys, such as 3003 and 6063 have a ratio of 8 in. wide to 3/32 in. thick; for 2014, it is 8 in. wide to ⅛ in. thick.

DESIGN RULES

1. Extruded shapes are usually restricted to those that can be contained within a circumscribing 17-in. circle. Within this range, parts can be made as solid, hollow or semihollow shapes; T, L or V sections; rectangles; and complex shapes.
2. Avoid extremely thin sections within a large circumscribing area.
3. Avoid semihollow sections with unbalanced die tongues.
4. Avoid sections with extreme thickness variation.
5. Avoid hollow shapes having unsymmetrical voids or inadequate thickness between voids.

STEPPED EXTRUSIONS

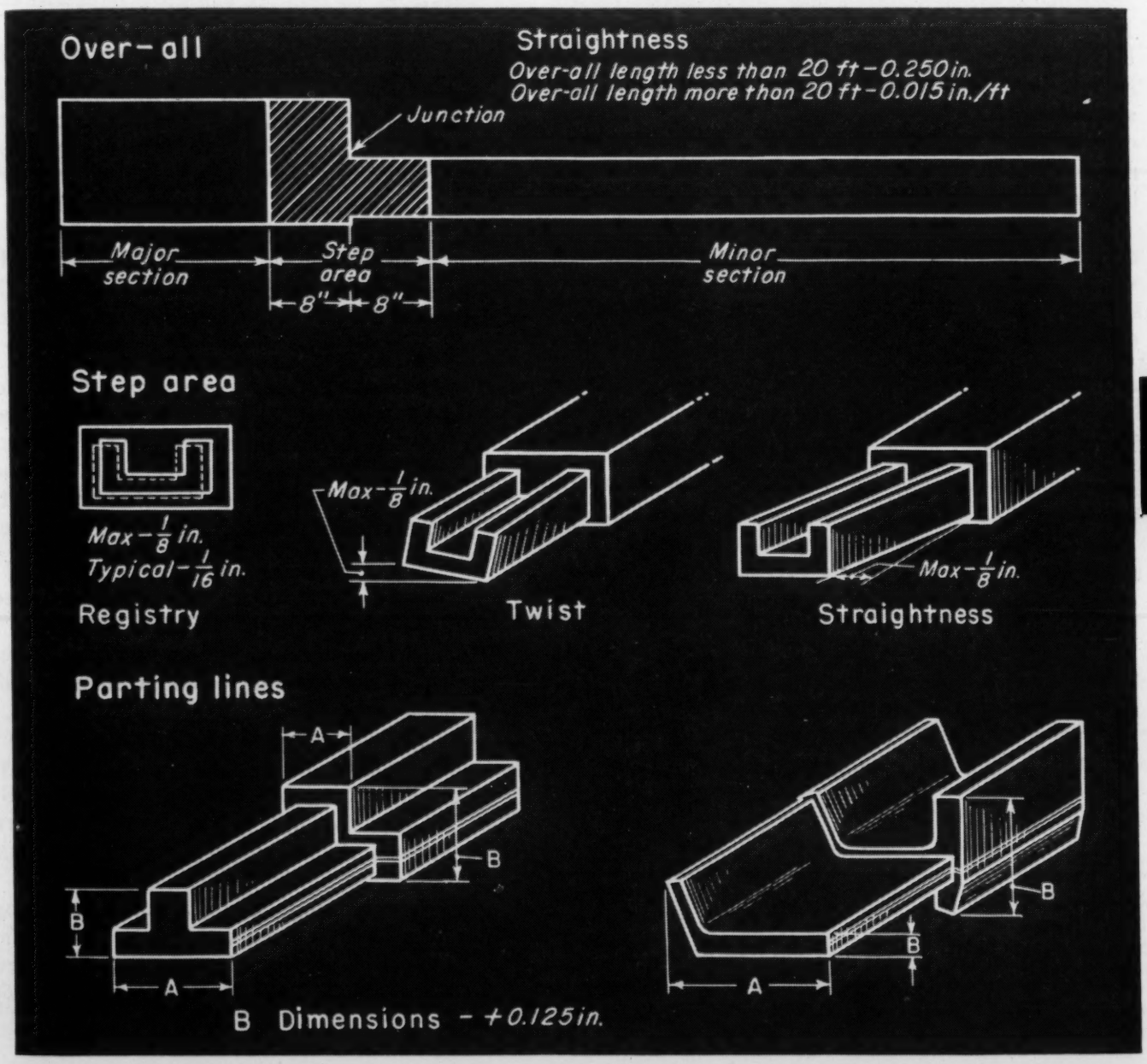
Stepped extrusions are commonly produced by utilizing two sets of extrusion dies.

In designing a stepped extrusion it is important to use dimensional tolerances that are realistic, yet avoid an excess of stock. Stepped extrusion tolerances have not been standardized, but those given in the accompanying sketches are typical. Straightness tolerances differ from those for normal extrusions. In addition, special tolerances apply to the step area and across the parting line when split dies are used.

Because of the inherent instability of split dies, cross section tolerances of stepped extrusions are usually greater than for normal extrusions. In locating parting lines, it is important to consider not only tolerances but also the ability to remove tools from the section. It is sometimes necessary to provide slight draft angles on extended elements.

Although the major and minor sections may frequently have a common plane, this is not a requirement of the process. In all cases, however, the major section must completely enclose the minor section. It is generally necessary to provide machining stock on all surfaces to obtain the required dimensional accuracy and surface finish.

Straightness of the over-all part is measured by deviation from a reference line, the junction or step area (8 in. on either side of the step) being excluded. Straightness of the minor or major portion of the extrusion is determined individually. Because of the difference in flow conditions in extruding the major and minor sections, the junction area usually presents the greatest straightening problems. Minor and major portions are usually furnished to standard extrusion straightness tolerances.



Impact Extrusions

GENERAL

Parts made by impact extruding cannot be very large or very small. They must be concentric in design, but can be provided with lugs, flutes and similar projections. Mechanical properties of impact extruded parts are usually high because of the tremendous amount of cold work involved in the process; this is particularly true of carbon steels.

Often a concentric impact extrusion is sectioned after forming to make two or more parts which could not otherwise meet the design requirements of impact extrusion. Examples are semicircular and U-shaped pieces.

Comparisons. Both impact extrusion and deep drawing use a combination of punch and die to form a hollow shell from a cold blank, and for some parts equivalent speeds are used. The difference lies in the manner in which deformation occurs. In impact extrusion the metal is forced through an orifice between punch and die under compressive stresses; in deep drawing the metal is pulled into the die by the punch and stressed in tension.

Both impact extrusion and ordinary extrusion force metal through a die under compressive stresses. However, the metal is generally cold worked in impact extrusion and hot worked in ordinary extrusion. In addition, impact extrusion produces a single component that may or may not require further operations, whereas ordinary extrusion generally produces a continuous cross section such as a rod, tube or structural shape.

An impact extruded part can be considered as a modified forging in which the flash forms the side walls. The part has a base that, in backward extrusion at least, is a forging, and side walls that are extrusions.

Advantages.

1. High speed production is possible.
2. Unit cost of mass produced parts is low.
3. Material saving and excellent metal recovery are achieved.
4. Process requires few operations. Ribs, fins, holes, etc., are formed during extrusion.
5. Parts have dimensional uniformity with close diametrical tolerances.
6. Tooling is relatively cheap.
7. Surface finishes on the order of 20 to 70 microinches are obtainable.
8. Bottom thicknesses are independent of wall thicknesses.
9. Parts can be made with zero draft angles and sharp corner radii.
10. Parts have excellent properties; for example, cold formed low or medium carbon steel parts have mechanical properties equivalent to those of heat treated carbon and low alloy steels.

Limitations.

1. Relatively few alloys can be processed commercially at present.
2. Shapes that can be produced are limited.
3. Length-to-diameter ratio is restricted.
4. Maximum size of part is limited by press capacity.
5. Comparatively high equipment costs limit applications to relatively high production runs.

COMMERCIAL SIZE RANGES FOR ALUMINUM IMPACT EXTRUSIONS

Material	Wall Thickness, in.		Diameter, in.	
	Max	Min	Max	Min
1070 (collapsible tubes)...	0.010	0.0035	2½	⅜
1100, 3003.....	½[a]	0.010	6	¾
Medium Strength Alloys..	½[a]	0.040	5	¾
High Strength Alloys.....	½[a]	0.062	4	¾

[a]Some authorities state that the maximum wall thickness is "not known."

DESIGN FACTORS

Sizes. Part sizes and dimensional tolerances vary considerably, depending upon the metal. Some typical figures: in aluminum, wall thickness ranges from a maximum of ½ in. down to 0.010 in. in the soft alloys or 0.062 in. in the stronger alloys. Diameters of parts can be as great as 6 in. in the soft alloys and 4 in. in the hard alloys, and as small as ¾ in. Larger parts would require extremely high pressures, and smaller parts would involve excessive tool damage.

Tolerances. Typical commercial dimensional tolerances for aluminum are as follows. On walls as thin as 0.10 in., the tolerance can be held to 0.010 in. Over 0.15 in., the tolerance must be increased to 0.020 in. Diameters can be held to 0.010 in., but lengths are not usually guaranteed any closer than 3/16 in.

Materials. By far the most commonly used material for mechanical parts is aluminum and its alloys. More than a dozen different alloys are used, depending upon the end service requirements, but from the standpoint of extruding 1100 alloy is best.

In steels, best results are obtained with those containing up to 1.2% carbon, although several alloy steels are impact extruded regularly. Steel parts must be somewhat smaller and have greater wall thicknesses than similar parts in aluminum.

Magnesium slugs are heated to 500 to 700 F for impact extruding. Several different alloys can be used, but best results are obtained with alloy AZ31B.

Several other metals are impact extruded to a lesser degree. They include lead, tin, copper, zinc and zirconium.

Fabricated Sheet Metal Parts

STAMPINGS AND PRESS FORMED PARTS

General. Blanking, pressing, stamping and drawing all have certain similarities, and are all done on hydraulic or mechanical presses or drop hammers. Each process consists of shearing or deforming a flat blank of metal sheet or strip in a die.

In making blanked shapes, which are usually flat, the metal is deformed beyond the shear point so that a clean break results. In drawing or forming, the stresses involved exceed the elastic limit of the metal so that permanent deformation results. When extreme draws are required, it is often necessary to draw part of the way, then anneal the metal before making a subsequent draw.

Limitations. Stampings and press formed parts must be rather simple in shape, e.g., a flat blank such as a motor lamination, or a shell with a symmetrical contour. Flanges and other projections are costly to attain. Uneven shapes, severe bends and other special features require costly die work and often result in production difficulties.

Materials. Nearly any metal that can be rolled can be used for stampings and press formed parts; however, materials that are essentially springy in nature should be avoided. Materials commonly used are carbon steels, copper, brass, bronze, aluminum and magnesium alloys, zinc, titanium, nickel alloys, and some high alloy and stainless steels. Stampings can be made with section thickness as little as 0.003 to 0.005 in. but the majority of drawn and stamped shapes are made from thicker materials.

Dimensional tolerances. These vary with the thickness of the material being formed. Tolerances of ±0.001 in. are possible on small pieces, and tolerances on the order of ±0.003 in. are possible on large pieces. These tolerances apply primarily to thin sections; tolerances must be more liberal for thicker sections.

Stamped parts. The width of a projection should be greater than 1½ times the material thickness and never less than 3/32 in.

Pierced parts.

1. The diameter (or smallest dimension) of a hole should be greater than the metal thickness and never less than 0.030 in.
2. Distances between hole edges (or hole edge and blank edge) should be equal to or greater than the metal thickness.
3. Holes pierced near a bending edge should be at least 1½ times metal thickness plus bend radius from the right angle side.

Drawn shapes.

1. Bends in metals should be made as nearly at right angles to the grain or rolling direction of the metal as is possible. Bending across the grain means less likelihood of the metal tearing during drawing.
2. Radii, particularly those on the inside of shapes, should be as large as possible, especially at the bottom of the draw. A radius should always be at

COMPARATIVE FORMABILITY OF METALS [a]

Metal	Alloy	Rating
Aluminum	1100-O	100
	3003-O	95
Magnesium (hot formed)		95[b]
Aluminum	6061-O	92
	5052-O	80
	7075-O	75
	2024-O	75
	2014-O	75
Deep Drawing Steel	1010	75
Soft Copper		75[b]
Commercial Steel	1010	70
Soft Brass		70
Aluminum (as quenched)	7075-W	60
	2024-W	60
	2014-W	60
Aluminum	1100-¼H	50
Stainless Steel	Type 302	49
	Type 304	46
Aluminum	3003-¼H	45
Stainless Steel	Type 321	43
Aluminum	5052-¼H	40[b]
	1100-½H	40[b]
Stainless Steel	Type 347	40
Aluminum	3003-½H	35[b]
	5052-½H	30[b]

[a] Based on rating of 100 for 1100-O aluminum. [b] Tentative.

PENETRATION OF PUNCH THROUGH METAL IN BLANKING OR PIERCING OPERATIONS

Metal ↓	Annealed		Partially Cold Worked	
	Resistance to Shearing, psi	Reduction or Penetration, %	Resistance to Shearing, psi	Reduction or Penetration, %
Lead	3,500	50	—[a]	—[a]
Tin	5,000	40	—[a]	—[a]
Aluminum	8,000	60	13,000	30
Zinc	14,000	50	19,000	25
Copper	22,000	55	28,000	30
Brass	32,000	50	52,000	20
Bronze (90–10)	—	—	40,000	30
Tobin Bronze	36,000	25	42,000	17
Steel				
0.10% C	35,000	50	43,000	38
0.20% C	44,000	40	55,000	28
0.30% C	52,000	33	67,000	22
0.40% C	62,000	27	78,000	17
0.60% C	80,000	20	102,000	9
0.80% C	97,000	15	127,000	5
1.00% C	115,000	10	150,000	2
Silicon Steel	65,000	30	—	—
Nickel	35,000	55	—	—

[a] Anneals at room temperature.

continued

Fabricated Sheet Metal Parts—continued

MINIMUM BEND RADII FOR MAGNESIUM ALLOY SHEET[a]

Alloy ↓	Forming Temperature, F				
	70	300	400	500	600
M1					
Annealed (M1a)	5T	4T	3T	2T	1T
Cold Worked (M1h)	11T	8½T	6½T	4½T	—
AZ31					
Annealed (AZ31Xa)	3½T	2T	1½T	1T	—
Cold Worked (AZ31Xh)	7½T	3T			
AZ51X					
Annealed (AZ51Xa)	6T	4½T	3½T	2½T	2T
Cold Worked (AZ51Xh)	9T	6½T	4½T		

[a]Experimental values, where T = metal thickness.

MINIMUM BEND RADII FOR AUSTENITIC STAINLESS STEELS[a]

Annealed	½T to 1T
¼ Hard	1T to 2½T
½ Hard	2½T to 4T
¾ Hard	3T to 5T
Full Hard	4T to 6T

[a]Where T = metal thickness.

least equal to the thickness of metal being drawn.

3. Radii on the under side of flanges should be at least 1/16 in. in the lightest gages, ⅛ to 5/16 in. in medium thicknesses, and 1½ times the stock thickness in heavy metal.

4. Connecting radii should be larger than the stock thickness.

5. On blanked and shaped parts, depressions should not be deeper than twice the stock thickness. In certain cases, where a hole is permissible, the depressions can be greater because the metal can stretch further.

6. Draws should be as shallow as possible because they are easier to achieve and less costly than deep draws. A draw should never be more than 1½ times the punch diameter.

7. The punch should cover about 50% of the blank area in any draw.

8. Use flat bottoms where possible.

9. Beading, flanging or corrugation can be used to add stiffness.

10. When notching is required, it is done as a final operation so that the notching will not be distorted during the drawing operation.

11. Widest possible tolerances should be provided.

12. In designing shapes, and particularly the tooling required, the springback characteristics of the metals must be considered.

MINIMUM BEND RADII FOR ALUMINUM SHEET[a]

Gage, in. ↓	7075-O, 7075-W[b]	7075-T6	2024-O, 2024-W,[c] 2014-O	2014-T3	2024-T3, 2014-T6	6061-O
0.020..	1/32	3/32	1/64	1/16	1/16	0
0.025..	1/32	1/8	1/64	1/16	3/32	0
0.032..	1/16	5/32	1/64	1/16	3/32	0
0.040..	1/16	3/16	1/32	3/32	1/8	0
0.051..	3/32	1/4	1/16	1/8	3/16	0
0.064..	1/8	5/16	1/16	5/32	7/32	0
0.081..	5/32	3/8	3/32	7/32	9/32	0
0.091..	3/16	1/2	3/32	1/4	11/32	0
0.102..	3/16	5/8	3/32	5/16	7/16	0
0.125..	7/32	3/4	1/8	3/8	1/2	1/16
0.156..	3/8	1	5/32	7/16	5/8	1/8
0.187..	1/2	1¼	3/16	1/2	3/4	3/16

Gage, in. ↓	6061-T4	6061-T6	5052-O	5052-H32 ¼ Hard	5052-H34 ½ Hard	5052-H38 ¾ Hard
0.020..	1/32	1/32	0	0	0	1/32
0.025..	1/32	1/32	0	0	0	1/32
0.032..	1/32	1/32	0	0	0	1/32
0.040..	1/32	1/32	0	0	0	1/16
0.051..	1/16	1/16	0	0	1/32	1/16
0.064..	1/16	3/32	0	0	1/16	3/32
0.081..	3/32	1/8	0	1/32	1/16	1/8
0.091..	1/8	5/32	0	1/16	3/32	1/8
0.102..	1/8	3/16	0	3/32	1/8	3/16
0.125..	3/16	1/4	0	1/8	1/8	1/4
0.156..	5/16	5/16	0	5/32	3/16	1/2
0.187..	3/8	9/16	0	3/16	9/32	9/16

Gage, in. ↓	5052-H38 Hard	1100-H12 ¼ Hard	1100-H14 ½ Hard	1100-H16 ¾ Hard	1100-H18 Hard
0.020..	1/32	0	0	0	1/32
0.025..	1/32	0	0	0	1/32
0.032..	1/16	0	0	0	1/32
0.040..	1/16	0	0	0	1/16
0.051..	3/32	0	0	1/32	1/16
0.064..	1/8	0	0	1/16	3/32
0.081..	3/16	1/32	1/32	1/16	1/8
0.091..	1/4	1/16	1/16	3/32	1/8
0.102..	5/16	3/32	3/32	1/8	3/16
0.125..	3/8	1/8	1/8	1/8	1/4
0.156..	5/8	5/32	5/32	3/16	1/2
0.187..	3/4	3/16	3/16	9/32	9/16

[a]Minimum allowable radii for bending aluminum alloy sheet depend on thickness, temper and composition. Values given in the table are for 90-deg bends and should be increased for bends greater than 90 deg.
[b]Freshly quenched and formed within 2 hr max, or 24 hr max if iceboxed at 32 F.
[c]Freshly quenched and formed within ½ hr max, or 24 hr max if iceboxed at 32 F.

BEND ALLOWANCES IN STEEL SHEET *

Inside Bend Rad., in. ↓	Metal Thickness, in.								
	.022	.028	.035	.049	.065	.095	.120	.187	.250
.032	.00072	.00076	.00082	.00093	.00105	.00129	.00148	.00200	—
.0625	.00126	.00131	.00136	.00147	.00160	.00183	.00203	.00255	—
.093	.00180	.00185	.00191	.00202	.00212	.00238	.00257	.00309	—
.125	.00235	.00240	.00245	.00256	.00269	.00292	.00311	.00364	—
.156	.00289	.00294	.00300	.00311	.00323	.00346	.00366	.00418	—
.1875	.00344	.00349	.00354	.00365	.00378	.00410	.00420	.00473	—
.218	.00398	.00403	.00409	.00419	.00432	.00455	.00475	.00527	—
.250	.00453	.00458	.00463	.00474	.00487	.00510	.00529	.00582	—
.281	.00507	.00512	.00517	.00528	.00541	.00564	.00584	.00636	—
.3125	.00562	.00567	.00572	.00583	.00596	.00619	.00638	.00691	—
.343	.00616	.00620	.00626	.00637	.00650	.00673	.00693	.00745	—
.375	.00671	.00675	.00681	.00692	.00705	.00728	.00747	.00800	.00849
.406	.00725	.00730	.00735	.00746	.00759	.00782	.00802	.00854	.00903
.4375	.00780	.00784	.00790	.00801	.00813	.00837	.00856	.00908	.00958
.468	.00834	.00839	.00844	.00855	.00868	.00891	.00911	.00963	.01012
.500	.00889	.00893	.00899	.00910	.00922	.00945	.00965	.01017	.01067
.531	.00943	.00948	.00953	.00964	.00977	.01000	.01019	.01072	.01123
.5625	.00998	.01002	.01008	.01019	.01031	.01055	.01074	.01126	.01175
.593	.01052	.01055	.01061	.01072	.01084	.01108	.01127	.01179	.01230
.625	.01106	.01111	.01117	.01128	.01140	.01161	.01183	.01235	.01284
.656	.01161	.01166	.01171	.01182	.01194	.01218	.01237	.01289	.01339

*Allowance for 1 deg of bend; multiply value in table by number of degrees in bend.

BEND ALLOWANCES IN ALUMINUM ALLOY SHEET *

Inside Bend Rad., in. ↓	Metal Thickness, in.								
	.020	.025	.032	.040	.051	.064	.081	.091	.128
.032	.00070	.00074	.00079	—	—	—	—	—	—
.0625	.00125	.00129	.00135	.00140	.00149	.00159	—	—	—
.093	.00179	.00183	.00188	.00195	.00203	.00213	.00226	.00234	—
.125	.00234	.00238	.00243	.00249	.00258	.00268	.00281	.00289	.00317
.156	.00288	.00292	.00297	.00304	.00312	.00322	.00335	.00343	.00372
.1875	.00342	.00347	.00352	.00358	.00367	.00377	.00390	.00398	.00449
.218	.00397	.00401	.00406	.00412	.00421	.00431	.00444	.00452	.00481
.250	.00451	.00455	.00461	.00467	.00476	.00486	.00499	.00507	.00535
.281	.00506	.00510	.00515	.00521	.00530	.00540	.00553	.00561	.00590
.3125	.00560	.00564	.00570	.00576	.00584	.00595	.00608	.00616	.00644
.343	.00615	.00619	.00624	.00630	.00639	.00649	.00662	.00670	.00699
.375	.00669	.00673	.00679	.00685	.00693	.00704	.00717	.00725	.00753
.406	.00724	.00728	.00733	.00739	.00748	.00758	.00771	.00779	.00808
.4375	.00778	.00782	.00787	.00794	.00802	.00812	.00826	.00834	.00862
.468	.00833	.00837	.00842	.00848	.00857	.00867	.00880	.00888	.00917
.500	.00877	.00891	.00896	.00903	.00911	.00921	.00935	.00943	.00971
.531	.00942	.00946	.00951	.00957	.00966	.00976	.00989	.00997	.01051
.5625	.00996	.01000	.01005	.01012	.01020	.01030	.01043	.01051	.01080
.593	.01051	.01055	.01058	.01065	.01073	.01083	.01098	.01105	.01133
.625	.01105	.01109	.01114	.01121	.01129	.01139	.01152	.01160	.01189
.656	.01160	.01164	.01170	.01175	.01183	.01193	.01207	.01214	.01245

*Allowance for 1 deg of bend; multiply value in table by number of degrees in bend

continued

Fabricated Sheet Metal Parts—concluded

THICKNESS TOLERANCES FOR DRAWN PARTS (In.)

Thickness, in. ↓	Up to 2 In. Dia	Up to 6 In. Dia
1/32	±0.005	±0.008
1/16	±0.006	±0.010
3/32	±0.008	±0.012
1/8	±0.010	±0.015
1/4	±0.015	±0.020

RECOMMENDED MAXIMUM REDUCTIONS IN DRAWING (%)

Low Carbon Steel	45
Austenitic Stainless Steels	50
Copper	45
High Brasses (70–30, 63–37)	50
Tin Bronze	50
Aluminum (annealed, 1/4 hard)	45
Aluminum Alloys	
Annealed, 5052 (1/4 hard)	45
Heat Treatable, As Quenched	40
Zinc	40

MINIMUM PUNCH RADIUS FOR DRAWING CUPS[a]

Ratio of Draw Depth to Draw Dia ↓	Steel		Aluminum	
	SAE 1010	Stainless 302, 304	1100-O, 3003-O 5052-O, 6061-O	2024-O, 2014-O, 7075-O
1/4	1/2T	2T	1T	2T
1/2	1T	—	2T	3T
3/4	2T	—	3T	4T
1	—	—	4T	—

[a]Where T = thickness of material.

ROLL FORMED SHAPES

Roll formed shapes have been produced from material 1/2 to 3/4 in. thick, but usually the material used in roll forming is less than 0.125 in. thick. Roll forming machines are capable of handling sheet and strip varying in width from a fraction of an inch up to as much as 80 in., though most shapes are made from material less than 20 in. wide.

Dimensional tolerances must be comparatively liberal, primarily because of variations in the thickness of the raw material. Usually dimensional tolerances of ±0.002 to 0.015 in. must be allowed.

PERMISSIBLE STRETCH IN STRETCH FORMING THIN-WALLED SECTIONS (%)

Aluminum Alloys	
2024-O, 7075-O	10
2024 (-O, -T or as-quenched)	6[a]
6061-O, 5052-O	25
Austenitic Stainless Steels (type 301)	
Annealed	20[b]
1/4 Hard	15–20
1/2 Hard	5–10
3/4 and Full Hard	2

[a]Up to 10% in the web.
[b]Up to 30% for symmetrical and rigid sections.

MINIMUM HOLD-DOWN PRESSURES (Psi)[a]

Low Carbon Steel	500
Austenitic Stainless Steels	1000
Aluminum	100
Aluminum Alloys	200–500
Copper	200
Brasses	250–300
Phosphor Bronze	400

[a]Per unit hold-down area.

SHORT RUN, PRESS FORMED PARTS

In the past, stampings and press formed parts could only be considered when huge quantities of parts were required. During the past few years, however, new techniques have been developed to extend the advantages of press forming to relatively small quantities of parts. These methods utilize soft die materials (which are easily worked but have short service lives), rubber blankets, or flexible punches or dies. These materials reduce die costs sufficiently to permit amortization of costs over comparatively small quantities of finished shapes.

Rubber pad. In the rubber pad or Guerin process, a rubber block or pad in the head of the press is used as the second die member to form a sheet metal blank around a punch or form block.

Flexible female die. One method is typified by the Hydroform press, which uses a flexible diaphragm covering a cavity filled with hydraulic fluid. The other method, the Marform press, utilizes a solid rubber pad which holds the blank, while regulated hydraulic pressure allows the punch to move into the pad, forming the part.

Flexible punch. Water or soluble oil is used as the male die member to force the sheet metal to conform to the configuration of the female die.

Drop hammer forming. Zinc-base alloys and lead are normally used for the dies since their low melting points permit rapid and economical fabrication of tools. In simple drop hammer work, there is no hold-down force on the blank; therefore, commonly encountered shapes have flanges and shallow depressions rather than drawn recesses. Parts are formed rather than drawn. Relatively deep draws can occasionally be accomplished with auxiliary devices and fixtures. Reverse contours and saddleback shapes are particularly difficult to form with a drop hammer.

RECOMMENDED LIMITATIONS FOR RUBBER PAD FORMING

Metal ➡	Heat Treatable Aluminum Alloys		Austenitic Stainless Steels	
	-O	-T	Annealed	¼ Hard
Max Sheet Thickness, in....	0.187	0.064	0.078	0.032
Recommended Flange Width (straight, not >90 deg), in.[a].....	1/16+	1/8+	3/16+	
Max Metal Thickness for Forming Flanges, in.	2.5 T	4 T	4.5 T	5/8
Stretch Flanges.....	0.125	Special methods required	0.050	0.016–0.030
Lightening Hole Flanges..	0.125	0.064	External 0.060, internal 0.050	External 0.040, internal 0.030

[a]T = metal thickness.

PERMISSIBLE STRETCH IN PRESS-DIE AND HYDROPRESS RUBBER FORMING STRETCH FLANGES (%)

Aluminum Alloys	
2024 (-O or as-quenched)	18[a], 12[b]
7075 (-O or as-quenched)	18,[a] 12[b]
2024-T	12[a], 8[b]
7075-T	7[a]
6061-O, 5052-O	30
Stainless Steels	
301, 302, 304, 305, 308 (annealed)	40
321, 347, 316, 330 (annealed)	30
301, 302 (¼ hard)	25
301, 302 (½ hard)	10

[a]Routed edge. [b]Sheared edge.

RECOMMENDED SINGLE DRAW LIMITATIONS FOR MARFORM PROCESS

Cup Dia, in. ⬇	Max Depth of Draw at Indicated Pressure, in.		Min Thickness, in.
	6000 psi	12,000 psi	
1	1/3	3/4	0.008
2	2/3	1½	0.010
3	1	2¼	0.015
4	1⅓	3	0.020
5	1⅔	3¾	0.025
6	2	4½	0.030
7	2⅓	5¼	0.035
8	2⅔	6	0.040

MAXIMUM CUP DEPTH IN MARFORM PROCESS[a]

Metal Thickness, in.	Max Cup Depth, in.
0.064	5⅛
0.050	4⅞
0.037	4¾
0.032	4½

[a]Based on reduction from 12-in. dia blank to 4¼-in. dia cup, 15,000 psi forming pressure.

Forgings

FORGEABLE METALS

Carbon steels. Low carbon (up to 0.25%) forgings for moderate conditions and for carburized parts where resistance to abrasion is important. Medium carbon (0.30 to 0.50%) forgings for more severe service; some heat treatment is generally desirable. High carbon (> 0.50%) forgings for hard surfaces and springs; heat treatment is essential to obtain other desired properties.

Alloy steels (manganese, nickel, nickel-chromium, molybdenum, chromium, vanadium, chromium-vanadium, tungsten, silicon-manganese). Forgings from these steels are used wherever higher strength, resistance, durability, etc., are wanted. The proper selection of a particular composition, together with its subsequent heat treatment, depends upon the particular service requirements of the part.

Corrosion and heat resisting, and stainless, steels. These steels are usually high in chromium or nickel, or both. The particular type of corroding agent to be encountered determines the best composition. Generally, but not necessarily, forged surfaces should be polished to obtain full benefit of corrosion resistance properties.

Iron. Wrought iron and ingot iron are forged for special applications where ductility is required. Wrought iron furnishes a moderate degree of corrosion resistance. The copper-bearing irons and low carbon steels are in this class.

Copper, brasses, bronzes. Copper forgings have extensive applications in the electrical field. The brass and bronze alloys have moderate corrosion resistance properties. Some of the bronzes have moderately high strength and good bearing properties.

Nickel, nickel-copper alloys. Pure nickel is forgeable. The alloy of nickel and copper known as monel metal offers a desirable combination of strength, toughness and corrosion resistance.

Light alloys (aluminum, magnesium). The light alloys have about one-third the weight of steel, and some have approximately the strength of low carbon steel. Forgeable alloys are available in both the aluminum and magnesium groups.

COMMERCIAL FORGING PRACTICE

Impression die forgings are sold by the piece and not by the pound. It is understood without specific mention that the excess metal or flash of forgings shall be removed by trimming, and that forgings shall be free from injurious defects.

Quantity. The quantity specified permits standard practice limits on over-runs and under-runs.

Size. Forgings within commercial size limits will be furnished unless closer tolerances are specified.

Coining or sizing. Closer tolerances may be obtained by additional hot or cold sizing operations.

Surfacing conditions. Forgings are furnished in a cleaned condition obtained by tumbling, pickling or blast cleaning unless otherwise specified.

Special requirements. Any special requirement, such as heat treatment or special tests, should be clearly stated.

Preparation charges. The production of impression die forgings requires the preparation of special dies and tools which may be charged to the customer as a separate item called "preparation charges." The customer has the exclusive right to use such dies and tools, but because the full cost is generally not included in such a charge he does not have the right to remove them without additional payment. Any such dies and tools are maintained in the future without further charges to the customer.

TOLERANCES

Standard tolerances given on these pages are for forgings up to 100 lb.

Special tolerances may be specified when regular tolerances are not applicable. Regular tolerances, shown here, are classed as "Commercial Standard" and "Close Standard."

MISMATCHING TOLERANCES*

Weight of Part ↓	Commercial, in.	Close, in.
Net Weight up to . . .		
1 lb	0.015	0.010
7 lb	0.018	0.012
13 lb	0.021	0.014
19 lb	0.024	0.016
Each Additional 6 lb Add...	0.003	0.002
For Example:		
37 lb	0.033	0.022
55 lb	0.042	0.028

*Mismatching tolerances are independent of, and in addition to, any other tolerances. Mismatching is the displacement of a point—in that part of a forging formed by one die block of a pair—from its desired position when located from the part of the forging formed in the other die block of the pair. Mismatching does not include any displacement caused by variation in thickness of the forging, but is only the displacement in a plane parallel to the main or fundamental parting plane of the dies

SHRINKAGE AND DIE WEAR TOLERANCES *

Length or Width, in. ↓	Shrinkage		Max Net Wt, lb ↓	Die Wear	
	Commercial, in. ±	Close, in. ±		Commercial, in. ±	Close, in. ±
1	0.003	0.002	1	0.032	0.016
2	0.006	0.003	3	0.035	0.018
3	0.009	0.005	5	0.038	0.019
4	0.012	0.006	7	0.041	0.021
5	0.015	0.008	9	0.044	0.022
6	0.018	0.009	11	0.047	0.024
For Each Additional Inch Add	0.003	0.0015	For Eadh Additional 2 Lb Add	0.003	0.0015
For Example:			For Example:		
7	0.021	0.011	13	0.050	0.026
12	0.036	0.018	21	0.062	0.031

*Shrinkage and die wear tolerances shall not be applied separately. They shall be applied as the sum of the two and shall be measured in such a way as to eliminate draft or variations in draft. They apply to that part of the forging formed by a single die block, and to no dimension crossing the parting plane.

DRAFT ANGLE TOLERANCES

Type ➡	Drop Forgings		Upset Forgings	
	Outside, deg	Inside Holes, deg	Outside, deg	Inside Holes, deg
Nominal Angle	7	7 or 10	3	5
Commercial Limits	0–10	0–13	0–5	0–8
Close Limits	0–8	0–8	0–4	0–7

QUANTITY TOLERANCES *

No. of Pieces on Order ↓	Over-Run, pieces	Under-Run, pieces	No. of Pieces on Order ↓	Over-Run, %	Under-Run, %
1–2	1	0	100–199	10	5.0
3–5	2	1	200–299	9	4.5
6–19	3	1	300–599	8	4.0
20–29	4	2	600–1249	7	3.5
30–39	5	2	1250–2999	6	3.0
40–49	6	3	3000–9999	5	2.5
50–59	7	3	10,000–39,999	4	2.0
60–69	8	4	40,000–299,999	3	1.5
70–79	9	4	300,000 up	2	1.0
80–99	10	5			

*Quantity tolerances shall be the permissible over or under-run allowed for each release or part shipment of an order. Any shipping quantity within the limits of over and under-run shall be considered as completing the order. Commercial and close tolerances shall be the same amounts.

THICKNESS TOLERANCES *

Max Net Wt, lb ↓	Commercial, in.		Close, in.	
	Minus	Plus	Minus	Plus
0.2	0.008	0.024	0.004	0.012
0.4	0.009	0.027	0.005	0.015
0.6	0.010	0.030	0.005	0.015
0.8	0.011	0.033	0.006	0.018
1.0	0.012	0.036	0.006	0.018
2.0	0.015	0.045	0.008	0.024
3.0	0.017	0.051	0.009	0.027
4.0	0.018	0.054	0.009	0.027
5.0	0.019	0.057	0.010	0.030
10.0	0.022	0.066	0.011	0.033
20.0	0.026	0.078	0.003	0.039
30.0	0.030	0.090	0.015	0.045
40.0	0.034	0.102	0.017	0.051
50.0	0.038	0.114	0.019	0.057
60.0	0.042	0.126	0.021	0.063
70.0	0.046	0.138	0.023	0.069
80.0	0.050	0.150	0.025	0.075
100.0	0.058	0.174	0.029	0.087

*Thickness tolerances for drop hammer forgings apply to the over-all thickness measured in a direction perpendicular to the fundamental parting plane of the dies. For upset forgings, thickness tolerances apply to the metal actually enclosed and formed by the dies, measured parallel to the direction of travel of the ram.

FILLET AND CORNER TOLERANCES *

Max Net Wt, lb ↓	Commercial, in.	Close, in.
0.3	3/32	3/64
1.0	1/8	1/16
3.0	5/32	5/64
10.0	3/16	3/32
30.0	7/32	7/64
100.0	1/4	1/8

*Fillet and corner tolerances apply to all intersection surfaces, even though drawings or models indicate sharp corners. If such drawings or models have or indicate fillet or corner dimensions of larger radii than these standards, such larger dimensions shall be considered as actually specified and the tolerances shall be "special tolerances."

Where a corner tolerance applies on the meeting of two drafted surfaces, the tolerance shall apply to the narrow end of such meeting and the radius will increase toward the wide end. The total increase in the radius will equal the length of the drafted surface in inches, multiplied by the tangent of the nominal draft angle.

Plastics Parts

The form in which plastics materials should be specified is largely determined by the nature of the material. Plastics resins are either thermoplastic or thermosetting in nature. Thermoplastic resins soften and flow when heated and harden when cooled. For moldings, the polymer is usually supplied in granular form. After being heated to the fluid state it is charged to the mold or die, where it cools and hardens.

Thermosetting plastics do not soften when heated, but gradually lose properties as temperature increases, until they char and disintegrate. For moldings, thermosetting resins are usually supplied in a partially polymerized granular form, usually with some type of fibrous reinforcement. They flow to a limited degree on initial heating, but as heating continues they polymerize completely and cure to a hard infusible state.

MOLDED PARTS

Injection molded parts. The injection molding process for plastics is similar in nature to the die casting process for metals. A thermoplastic molding compound is heated to plasticity in a cylinder at a controlled temperature and forced under a pressure of 10,000 to 50,000 psi through sprue, runners and gates into a cool single or multiple cavity mold. The resin solidifies rapidly, the mold is opened, and the part or parts ejected.

The primary advantage of the process, as is the case with die castings, is the relatively low cost per part. Multiple cavity molds can often be used. The cycle is rapid, since parts can be removed from the mold as soon as they solidify sufficiently.

In some cases modifications of the injection molding process can be used to mold small parts of thermosetting resins. These processes are called jet, flow or offset injection molding. They make use of the fluid state of thermosetting molding materials before complete polymerization. The process is suitable only for relatively small parts, and is one that requires careful control of processing variables, such as temperature.

Compression molded parts. Compression molding is primarily used to mold thermosetting plastics, though in some instances it can be used economically to mold thermoplastics, e. g., vinyl phonograph records. Thermoplastic materials cannot usually be preformed, but are charged as powder or granules.

In compression molding, a partially polymerized thermosetting resin, usually in the form of a preform made from powder or granules, is placed in the heated mold cavity. The mold is closed, heat and pressure are applied, and the material flows and fills the mold cavity. The heat then fully polymerizes the material before the mold is opened and the part removed.

In the case of thermoplastic materials, heating softens the polymer, which flows and fills the mold. Then the mold is cooled and the part solidifies.

Less material is required for compression molding than for injection or transfer molding, since the material is placed directly in the mold, and no sprues, runners or gates are required. With thermosetting resins, the cycle is longer than in injection molding, since the part must be cured in the mold.

Cold molded parts. Cold molding is similar to compression molding in that it makes use of a split, or open, mold in which the material is charged. It differs from compression molding in that it uses no heat—only pressure on the order of 2000 to 12,000 psi. After the part is removed from the mold it is placed in an oven to cure to its final state.

Materials used for cold molding are classified as nonrefractory (organic) and refractory (inorganic). Organic types consist of binders — such as asphalts, oil derivatives and residues, and gum or resin solutions — and fillers, such as asbestos fibers and silica and magnesia compounds. Inorganic types consist of binders — such as cement, lime or silica — and fillers, such as asbestos.

Cold molded parts are primarily used for electrical components. The materials have excellent electrical insulating properties, as well as resistance to moisture and heat.

Transfer molded parts. Transfer molding of thermosetting materials is roughly analogous to injection molding of thermoplastics. The thermosetting molding compound is heated to plasticity in a transfer chamber, and is then fed to the mold cavity (or cavities) through sprue, runners and gates. After the mold is filled, heat is maintained for a predetermined period of time to fully polymerize and cure the part.

In comparison with compression molding, transfer molding is particularly advantageous where thin sections or delicate inserts are used. Since the design of runners and gates permits some control over where the material is to be fed to the mold, flow of the material can be more closely controlled than in compression molding. Also, closer tolerances can usually be held on transfer molded parts. On the other hand, transfer molds are usually more elaborate than compression molds, and there is a loss of material in the cull and sprue. Size of transfer molded parts is somewhat limited.

Design factors. Though it is difficult to generalize about design factors for injection, compression and transfer moldings, the following factors should be considered:

Shrinkage—Allowance must be made for shrinkage of the molding compound in design of the part. In addition to affecting dimensional accuracy of the part, shrinkage can introduce internal stress which may make the part unserviceable. Shrinkage values for the various plastics are given in the data sheets in Section 5 of this issue.

Wall thickness—Strength required both in service and during manufacture must be considered in designing wall thickness. In thermosetting materials, walls less than 0.062 in. thick are extremely difficult to obtain, and a minimum of 0.125 in. is preferred (see accompanying table).

Draft—A draft taper in deep drawn parts, in addition to making it easier to remove a part from the mold, creates a wedging action as the the mold is closed. When thermosetting materials are compression molded, converging tapers increase the density of the plastic in the upper sections. There are no precise formulas for taper, but the most liberal taper the design can allow should be provided. Tapers of less than 1 deg can be used for deep parts; e.g., television cabinets 6 to 24 in. deep have been molded with tapers as small as 0.001 in. per in.

Tolerances—A high degree of accuracy in molded parts is expensive to achieve. On small shapes, tolerances as close as ± 0.002 in. are possible. When

size is increased to a few inches, over-all tolerances increase to approximately ±0.005 in. On large pieces, tolerances of about ±0.001 to 0.002 in. per in. are obtainable. Tolerances closer than actually mandatory should not be specified; as specified accuracy increases, cost increases disproportionately.

Design Rules.

1. Use sufficient draft on long thin shapes to permit their withdrawal from the mold.

2. Minimize coring. When cores are used they should be easy to withdraw.

3. Avoid internal and external undercuts; they make withdrawal of parts difficult and require considerably more expensive molds.

4. Provide ample fillets on inside corners, and avoid sharp external edges and corners except at the parting line of the die.

5. Avoid large flat areas. Dappling or otherwise breaking up the surface is recommended.

6. Keep tolerances as liberal as possible. Excessively close tolerances add to cost because of increased die costs and high rejection rate.

7. Avoid abrupt changes in wall thickness.

8. Locate parting lines so that flash can be removed easily without marring surrounding areas.

9. Locate holes for easy coring.

10. Use ribs to achieve desired strength and stiffness. Ribs permit materials savings by reducing section thickness.

11. Use inserts for threaded holes where high stresses are anticipated or where considerable wear is to be encountered. Round inserts are preferred.

WALL THICKNESS OF MOLDED PARTS (In.)

Material ⬇	Minimum	Small Parts	Average	Large Parts
THERMOSETTING				
Phenolics				
General Purpose & Flock-Filled	0.050	0.062	0.125	0.187–1.000
Fabric-Filled	0.062	0.125	0.187	0.187–0.375
Mineral-Filled	0.125	0.125	0.187	0.200–1.000
Alkyd				
Glass-Filled	0.040	0.093	0.125	0.187–0.500
Mineral-Filled	0.040	0.125	0.187	0.187–0.375
Ureas, Melamines				
Cellulose-Filled	0.035	0.062	0.100	0.125–0.187
Fabric-Filled	0.050	0.125	0.125	0.125–0.187
Mineral-Filled	0.040	0.093	0.187	0.187–0.375
THERMOPLASTIC				
Acrylics	0.025	0.035	0.093	0.125–0.250
Cellulose Acetate	0.025	0.050	0.075	0.125–0.187
Cellulose Acetate Butyrate	0.025	0.050	0.075	0.125–0.187
Ethyl Cellulose	0.035	0.050	0.062	0.093–0.125
Polyamide	0.015	0.025	0.060	0.093–0.125
Polyethylene	0.035	0.050	0.062	0.093–0.125
Polystyrene	0.030	0.050	0.062	0.125–0.250
Polyvinyl Chloride	0.093	0.062	0.093	0.125–0.250

CASTINGS

Materials. Any resin available in liquid form can be cast. Castable resins include phenolics, polyesters, epoxies, silicones and acrylics.

Types of molds. The type of mold used depends on the plastic, the size and shape of the part, and other design considerations.

Draw mold—No undercut is possible. Flutes and scallops must run in the direction of removal. Taper must be provided to break the vacuum and reduce friction. Castings are removed by force, and minimum wall thickness is critical, running from 1/8 in. on tiny parts to 3/16 in. on parts the size of radio cabinets.

Split mold—Undercuts may be provided if they do not prevent release from the separate parts of the mold. Minimum wall thickness is 3/16 in., and parts less than 0.1 lb are not commonly produced economically.

Cored mold—This type allows complexity of design, but is not usually feasible from a cost standpoint for parts less than 4 x 4 x 4 in. Molds require no taper. Minimum wall thickness is 3/16 in. Mold shrinkage allowance must be considered. Extremely large parts may be cast.

Flexible mold—Model may be constructed of wood porcelain, metal, etc. Mold is of plaster with a lining of rubber latex or an elastomeric plastic. Epoxy materials may be cast in flexible molds, but most polyesters react with the lining material. Although parts cast in rubber molds cannot be held to the tolerances possible with matched metal molds, a reasonable degree of accuracy is reproducible. For example, on cast phenolic parts dimensions can be held to about ±0.004 in. per in. The degree of accuracy obtainable on any part depends on the oversize allowance used in making the master pattern, the care with which the pattern is made, and the degree of accuracy attained in calculating amount of shrinkage during cure of the rubber mold and the cast resin.

EXTRUSIONS

In many cases, extruded parts are competitive with molded parts. Where many parts are required with a complicated cross section in one plane, the cross section can be produced by extrusion, and the parts formed by rapid, automatic cut-off to shape.

Thermoplastics. In extruding a thermoplastic, the molding powder is fed through a hopper to a chamber in which it is heated to plasticity at a controlled temperature. The plastic powder is then driven, usually by a rotating screw, through a die having the shape of the desired cross section. The process is continuous and is used to produce tube, rod, film and sheet, as well as other continuous shapes.

Thermosets. Reinforced thermosetting tube and rod can be produced by an extrusion process. The reinforcing fibers are fed continuously through a bath of liquid thermosetting resin and then through a die of the desired cross section. The extruded shapes then pass through a cylinder held at a controlled temperature to polymerize and cure the thermosetting resin. Extrusion speed must be relatively slow to provide sufficient time for complete cure.

continued

Plastics Parts—continued

THERMOPLASTIC SHEET FORMED PARTS

Materials. A variety of shapes and forms can be produced by thermoforming calendered, cast or extruded thermoplastic sheet. The materials that lend themselves to this method of forming include polystyrene and modified polystyrenes, acrylics, cellulose acetate and cellulose acetate butyrate, vinyl polymers and copolymers, and polyethylene. Use of this type of molding has grown with the development of relatively low cost extruded sheet to replace more expensive cast or calendered materials.

Methods. Essentially, thermoforming involves preheating the flat sheet to 180 to 360 F, the temperature depending on the material, and then forming by mechanical, air or hydraulic pressure to the desired shape. After cooling, the part is taken from the mold, and unwanted flanges are sawed or blanked from the part. All of the different processes have in common low forming pressures, and thus low cost molds and equipment (see accompanying box for details on the types of parts producible by each method). In recent years, rapid-cycle forming machines have been developed to make sheet molding more practical for large production quantities.

REINFORCED PLASTICS MOLDINGS

The term "reinforced plastics moldings," as used here and in the plastics industry, refers to parts produced by impregnating a reinforcing material, in the form of cloth or mat, with a liquid thermosetting or thermoplastic resin, laminating the material into multiple layers, and curing with heat and pressure to form a dense, hard solid. It does not include materials discussed later as "high pressure laminates," which are available from stock as flat sheet, rod or tube.

Materials. Resins used for reinforced plastics moldings include polyesters, phenolics, epoxies, melamines and silicones. Reinforcements include cloth or mat made from cotton, glass, asbestos and nylon. Glass reinforcements are most commonly used. Recently, there has been much interest in reinforcing thermoplastic resins, such as vinyls and acrylics, with cloth or mat made from thermoplastic synthetic fibers such as nylon. However, the bulk of reinforced plastics moldings today utilizes thermosetting resins.

Methods.

Contact molding—A low cost mold is used. Layers of reinforcing material are placed by hand against the mold surface; and resin is added, either by spraying or brushing after each layer is located. After sufficient layers of mat or cloth have been saturated with resin, they are allowed to harden without external application of heat and without applied pressure.

Vacuum bag molding—Procedure is similar to contact molding except that when lay-up is completed, a flexible sheeting, usually polyvinyl alcohol, is placed over the impregnated reinforcement and a vacuum is drawn between the sheeting and the mold surface. This provides about 12 psi pressure on the part, permitting higher glass content.

Pressure bag molding—Similar to vacuum bag molding except that a tailored bag is placed against the sheeting, and pressure is applied inside the bag to expand it against the impregnated reinforcement (sometimes pressure is applied directly on the sheeting). Pressures up to 50 psi are usually used, making high glass contents practical. Sometimes the entire assembly is placed in a large autoclave that contains hot air or steam at 50 to 100 psi pressure ("autoclave molding").

Flexible plunger molding—A metal female mold is usually employed and glass and resin are placed in the heated cavity. The plug portion is made of medium hard rubber, and is the approximate shape of the part to be molded. The rubber plug provides uniform, high and fluid pressure. High glass contents are possible. This method is not practical for large moldings because of the high pressures and the limitations of the flexible plunger.

Vacuum injection molding—Two molds, often made of glass-reinforced plastics, are used. The reinforcement is laid between the two molds and the resin is poured in a moat around the bottom. The resin is then sucked by vacuum up through the reinforcement. This tends to give air-free parts, and is used primarily for large parts. Glass contents are usually low.

Matched die molding—Can be used for parts up to about 60 sq ft in area, and is generally used for high production runs. Uses two metal molds which have a close-fitting, telescoping area to seal in the resin and trim the reinforcement. The molds are heated (with steam or electricity) to about 240 F. Where the length of run is sufficient, this method gives the lowest cost moldings and the highest production rates.

Design rules. Designing molded reinforced plastics parts is difficult because of the large number of variables encountered in the material and the process, and the difficulty of controlling some of them. These variables include: 1) composition of the resin, including fillers, catalysts and hardening agents, 2) geometry of the reinforcing material, 3) resin-reinforcement ratio, 4) degree of saturation of reinforcement by resin, and 5) temperature and time of cure.

The cardinal design rule, which cannot be overemphasized, is: consult the custom molder in the primary design stages. In addition, follow these general design rules:

1. Integrate parts.
2. Make prototypes.
3. Mold to dimensions; parts cannot be "sprung" after they are molded.
4. Use stress formulas valid for fiber-reinforced plastics.
5. Know the conditions of use.
6. Consider effects of the molding procedure.
7. Use sandwich construction for maximum strength-to-weight ratios.
8. To increase rigidity in stressed areas: a) increase the glass loading, b) use unidirectional reinforcement where practical, c) place flanges and lips on edges, d) use ribs, corrugations, beads and dimples, e) increase wall thickness, f) use curved sections rather than flat areas where possible, and g) use sandwich construction.
9. Avoid drastic changes in wall thickness.
10. Avoid sharp corners; use liberal radii.
11. Use maximum draft.
12. Avoid undercuts.

THERMOPLASTIC SHEET FORMING METHODS

Cold bending. Simple circular or cylindrical shapes. The thicker the sheet, the larger the bend diameter must be to prevent high stress concentrations. Ex: consumer packages.

Hot line bending. Two-dimensional shapes with arc, angle or channel cross section. Gradual to sharp bends, depending on heating procedure. Ex: safety guards.

Stretch forming (hot draping, yoke forming). Two-dimensional or slightly compound shapes, especially large shapes. Subject to surface distortion. Not suitable for reproduction of fine details. Yoke forming provides more uniform thinning out and is suitable for longer runs than manual stretch forming. Ex: aircraft canopies.

Plug and ring forming. Shallow to deep drawn shapes with gradual to sharp angles and curves. Not suitable for highly accurate contours or fine mold details. Considerable surface distortion, especially at inside corners — unsuitable where optical properties are critical. Ex: trays.

Slip forming. Same as yoke forming or plug and ring forming except that much more uniform thickness and less optical or pattern distortion can be obtained throughout the part, especially in deep drawn shapes. Fluted edges obtained by increasing clearance. Ex: carrying cases.

Free blowing or free vacuum forming. Somewhat modified surface tension shapes (tending toward fishbowl shapes) determined by shape or clamping ring and depth of draw. Internal flanges. Tolerances ¼-½ in. Good optical properties. Vacuum method easier to control and preferred where 15 psi is sufficient pressure. Ex: aircraft domes.

Ridge forming. Simple or complex (with vacuum and/or air pressure) shapes with minimum surface distortion and low mold cost. Generous radii necessary to avoid tearing at ridges during forming. Combines possibilities of plug and ring forming, free blowing or free vacuum forming, vacuum forming and vacuum snapback forming. Ex: equipment housings.

Vacuum forming or blow molding in female mold. Usually limited to relatively shallow draws, and relatively large angles and radii—more so the thicker the sheet. Blow molding offers higher pressures and is therefore more suitable for smaller angles and radii, especially in thicker sheet; also reduces forming temperature required for thick sheet. Both produce some surface distortion—less so the more the shape of the mold resembles a surface tension shape. Ex: display signs.

Blow-dieing. Small, thin shapes having greatest perimeter larger than neck — especially closed spherical or modified spherical shapes. Not suitable for close tolerances. Ex: hollow toys.

Vacuum forming over male plug (drape forming). Shallow to deep drawn shapes with relatively sharp angles and curves can be made with good accuracy and reproduction of fine mold detail, and without excessive thinning out. More accurate than plug and ring forming but not as suitable for thick sheet. Subject to surface distortion, especially at bottom of draw. Ex: display signs.

Vacuum snapback forming. Especially suitable for modified surface tension shapes with minimum mark-off and closer tolerances (⅛ in.) than obtainable in free blowing or free vacuum forming. Simple snapback method not suitable for reverse curves or sudden contour changes, but more complex shapes and finer reproduction of mold detail are provided by additional vacuum or air pressure. Integral flanges. Combines possibilities of free vacuum forming and plug and ring forming. Ex: aircraft domes.

Matched die molding (embossing). Especially suitable for shallow draws, long runs and embossed surfaces. Relatively uniform thickness, good mechanical properties. Subject to surface distortion on both sides. Ex: watch crystals.

Die pressing. Small, simple shapes that can be approximated in precut blank and have somewhat varying thickness, or relatively great thickness compared to over-all size. Ex: brush backs.

13. Consider use of molded-in holes.
14. Consider mold shrinkage.
15. Design to practical dimensional tolerances.
16. Design to avoid warpage.

Secondary fabrication. See "High Pressure Laminates" below.

HIGH PRESSURE LAMINATES

The term "laminates" used here refers to those reinforced plastics materials formed by high pressures (over 1000 psi). Vulcanized fibre is also included because of the similarity of its applications. These materials are available as sheet, rod or tube.

Materials. Resins used include phenolics, melamines, silicones and epoxies, and reinforcements consist of

MINIMUM COLD BENDING RADII FOR RIGID VINYL SHEETS

Calendered		Planished	
Thickness, in.	Min Bend Rad., in.	Thickness, in.	Min Bend Rad., in.
0.005			
Long.	½	0.010	12
Trans.	2	0.020	12
0.010		0.030	14
Long.	1	0.040	14
Trans.	6½	0.050	18
0.015			
Long.	3		
Trans.	9		

continued

Plastics Parts—concluded

cellulose paper, asbestos paper, or fabric or mat made from cotton, glass, asbestos or nylon fibers. Vulcanized fibre has only one component—cellulose. It is made by laminating chemically gelled paper, leaching out the chemical, and calendering. The resulting laminate is tough and hornlike, and has good electrical properties. Properties of standard NEMA (National Electrical Manufacturers' Assn.) laminates are given in Section 5 of this issue.

Postforming. Certain grades of laminates can be postformed by the use of heat and pressure. Temperatures, times and pressures vary with grade of laminate, thickness of material, and design. Temperatures generally range between 350 and 480 F, heating time usually ranges from a few seconds to a few minutes at most, and pressures range from a few pounds to several hundred pounds per square inch.

Although the following formability values should not be used for design, they do indicate general limits for postforming. Minimum radii are measured on the inside of bends, and apply to bends made lengthwise and crosswise. Smaller radii can be achieved with cloth-base laminates by orienting the sheet so that bends are made diagonally to the warp and fill directions.

Thickness, in.	Min Bend Rad., in.
1/32	1/32
1/16	3/32
3/32	3/16
1/8	5/16
3/16	9/16
1/4	1
5/16	1 3/4
3/8	2 1/2

Postforming grade laminates can be drawn to moderate depths. Both paper and cloth-base laminates in 1/16-in. thickness can be drawn to a depth of about 1¼ in. in a 3-in. dia spherical cup.

Vulcanized fibre can be formed by the use of moisture and pressure. Water softens or plasticizes the fibre to the extent that it can be formed under relatively low pressures, usually between 200 and 500 psi. In addition to forming in matched die presses, vulcanized fibre can be formed in standard sheet metal angle brakes and in punch presses if the design is simple and only a little moisture is required.

Secondary fabrication. Machining and other secondary operations carried out on reinforced plastics are similar for both low and high pressure moldings, as well as for laminates.

Blanking and punching—Use of a punch press with a hard, well-made blanking or punching die is the accepted production method for cutting flat stock, putting holes into side walls of moldings, and other piercing steps. Punching of reinforced plastics results in holes that are 0.002 to 0.010 in. smaller than the punch. Blanking gives parts 0.001 to 0.005 in. larger than the die. In each case, these values depend on a relation based on the thickness and the proportion of reinforcement. This "shrinkage" causes the material to seize the dies, so that a strongly loaded spring stripper mechanism is desirable. It has been estimated that a pressure of 20,000 psi (on the shear-edge area) is sufficient for blanking, punching and shearing.

Shearing—Shearing of ½-in. thick stock is quite feasible. For best results, the piece should have a width of at least twice the thickness of the parent stock. Shear gibs must be snug and blades sharp.

Sawing—Abrasive cutting wheels should be used whenever possible; rigid mounting of both the wheel and the work is important. A metal cutting blade, if used, should have coarse, offset, wide-spaced teeth.

Drilling—Accurately located holes on side walls are difficult to mold. Where small runs are made, and where precision is required, drilling is recommended. There is no limit to the thickness that can be drilled.

Tapping—Tapping is seldom performed, because the strength of a screw and tapped hole system is inferior to that of a nut and bolt assembly. Where light duty connecting is called for, self-tapping screws are satisfactory.

Grinding—Widely used to provide the taper in glass fiber-reinforced plastics fishing rods. Satisfactory automatic machines are in common use. Standard coolants are employed so that rapid feeds and minimized wheel loading are possible.

Routing, milling, turning—Routing is a practical production edging process and is faster and more accurate than jig-sawing where moderate numbers of irregular holes are to be cut. Milling and turning are not frequently required, but can be readily accomplished. Well-sharpened carbide or diamond-tipped tools provide good efficiency; speeds and feeds appropriate for brass are recommended.

DESIGN FACTORS FOR GLASS-REINFORCED PLASTICS MOLDINGS•

Type of Molding ➡	Bag	Flexible Plunger	Vacuum Injection	Matched Die
Inside Radius (min), in.	½	½	½	⅛
Molded-In Holes	Large only	No	No	Yes
Trimmed-In Mold	No	No	No	Yes
Built-In Cores	Yes	Not rec	Yes	Not rec
Undercuts	Yes	Only slight	Not rec	No
Draft (min), deg	5	1	3	1
Thickness (min), in.	1/10	1/16	1/10	1/32
Practical Thickness (max), in.	1	¼	½	¼
Normal Thickness Variation, in.	±0.020	±0.015	±0.020	±0.008
Thickness Build-Up (max)	As desired	2 to 1 max	As desired	2 to 1 max
Corrugated Sections	Core better	Yes, 1-in. rad.	Yes	Yes
Metal Inserts	Yes	Not rec	Yes	Possible
Surfacing Mat	No	Yes	Not rec	Yes
Size of Part (max), sq ft	2000	100	1000	175
Metal Edge Stiffening	Not rec	Not rec	Not rec	Yes
Bosses	Possible	Possible	Possible	Possible
Fins	Yes	No	No	Short, yes
Molded-In Labels	Yes	Yes	Not rec	Yes
Raised Numbers or Letters	Yes	Yes	Yes	Yes

•Not rec=not recommended at present time.

Metal Powder Parts

GENERAL

Metal powder parts are made by compacting loose metal powders in a die and subsequently sintering the compact to form a structural part.

Advantages. Powder metallurgy permits the use of metallic combinations that would not be possible to melt, and permits close control over structure, which may be dense or porous as desired.

Limitations. Metal powder parts must be of relatively simple shape because: 1) dies must permit easy removal of parts, 2) most powders have poor flow qualities, and 3) it is difficult to transmit pressures through great depths of powder. Where other considerations make it practicable, more complex shapes can be produced by using costly, intricate dies and double-acting presses. Because powder metallurgy is not capable of holding extremely close dimensional tolerances, secondary sizing or coining operations are sometimes required. Size of metal powder parts is restricted both by available press sizes and by the difficulty of transmitting pressure through powder.

MATERIALS

Material combinations impossible by other processes are commonplace in metal powder parts. Among the materials used are iron, steels, stainless steels, monel, nickel, iron-copper, copper, brass, tin, tungsten, zirconium and various oxides and carbides.

Purity. Clean particle surfaces are essential to insure the good contact between particles needed for optimum mechanical properties. In addition, the presence of foreign particles must be held to a minimum. In most cases definite limits for impurities are set by either producer or purchaser or both.

Apparent density. Apparent density (sometimes called bulk density) is the weight of a unit volume (gm per cu cm, MPA 4-45 or ASTM B 212-48) of powder and is of particular importance in the pressing operation. The lower the apparent density, the greater the volume of powder needed to produce a part of given size. As apparent density decreases, therefore, deeper dies and longer plungers are required, posing increasing design problems.

Compressibility. The ability of a metal powder to be pressed is of importance from the standpoint both of fabrication and of end properties that can be attained. Compressibility—the ratio of the volume of the loose powder to the volume of the compact made from it—is affected by the physical characteristics of the powder particles and the distribution of particle sizes. In general, powders should have a high enough compressibility so that satisfactory final density can be obtained without need for excessive pressures.

Particle size distribution. Particle size distribution, also called sieve analysis, is usually expressed as the percentage by weight retained on each of a series of standard sieves of decreasing size. It must be closely controlled because it affects press feed, dimensional changes during sintering, porosity of the compact, final attainable density and strength.

In general, powders with particle sizes larger than 100 mesh are not used for structural parts. Commercial metal powders usually include a range of particle sizes so that the fine particles will fill the voids between the large particles to give high density.

Particle size distribution is difficult to measure and control. At present, particle size distribution can only be determined in commercial practice down to 325 mesh, whereas frequently 25 to 50%, and sometimes more, of a given powder is finer than 325 mesh.

Flow rate. The ease with which a metal powder can be fed into the die is determined by its flow rate (gm per min, MPA 3-45 or ASTM B 213-48). Low flow rates slow up automatic pressing operations and may require the use of vibrating equipment. Flow rate is influenced by particle shape, particle size distribution and amount of absorbed moisture.

Sintering properties. Sintering is usually done in an inert, reducing or neutral atmosphere, or in a vacuum. The sintering temperature of metal powders is critical, and for production purposes it is desirable to have a reasonably wide temperature range that can be maintained in presently available furnaces.

Dimensional changes occurring during sintering are also an important consideration, particularly from the standpoint of die design and the finish tolerances that can be maintained. The dimensional change brought on by sintering usually consists of shrinkage, although extension occurs with some powders under certain conditions.

Green strength. A metal powder in the pressed but unsintered condition ("green") is rather brittle and is susceptible to chipping or other damage. Green strength is an indication of the powder's ability to be handled without breakage after compacting and before the sintering operation.

Performance properties. Mechanical and physical properties of sintered parts are closely related to the final density that can be achieved under practical pressing pressures. In general, as density of a metal powder part increases, strength properties also increase, and at 100% density the properties theoretically will be at least equal to those of solid stock.

As yet, few standard tests for determining mechanical properties have been established, and in many cases conventional methods are not adequate.

DESIGN FACTORS

Tolerances. It is possible to hold ± 0.001 in. by coining. A tolerance of ± 0.005 in. can be held on axial dimensions without secondary operations.

Wall thickness. A wall as slight as 0.30 in. is possible on small parts, but a general rule calls for a minimum thickness of 0.32 in. per in. of length of the section. Large variations in section thickness are undesirable.

Design rules.

1. Cylinders, squares and rectangles are the most favorable shapes. When a shape deviates from these, it is essential that it be uniform in the direction of pressing.
2. Contours must be in a plane at right angles to the direction of pressing.
3. Avoid feather or knife edges; narrow, deep splines; thin projections; and sharp corners.
4. Radii of at least 0.010 in. should be provided in corners, and edges should be given a 45-deg chamfer.

Screw Machine Parts

GENERAL

Advantages. Perhaps the greatest advantage of screw machine parts is the extreme speed at which they can be produced. Production rates can reach—and even exceed—4000 parts per hr. Extremely close tolerances can be held. Finishes are usually superior to those attained by other methods. Since bar or tube stock is used as the raw material, mechanical properties are usually high.

Limitations. Scrap losses are usually high because the over-all size of the bar must be as great, or greater than, the largest diameter of the part.

Materials. Nearly any machinable metal can be used for screw machine parts if it is available in bar or tubular form. For best results, though, the material should be free machining and should not be too soft, too hard or too stringy (since such materials make it difficult to maintain production speeds and also cause inferior surface finish). The majority of screw machine parts are made from free-machining steels, free-cutting brasses, and aluminum and magnesium alloys.

DESIGN RULES

Restrictions are imposed by the requirement that all parts must have surfaces of rotation that are concentric with the axis of the stock being machined. However, interior and exterior undercuts are possible, and nearly any type of thread can be produced.

Square corners are not desirable. Chamfers are preferred, but if rounded edges are desired, liberal radii should be provided. Dimensions can be held to ±0.001 to ±0.003 in. without difficulty and, when necessary, they can be as close as 0.0005 in.

Maximum size is limited, but screw machine parts can be extremely small. The range of sizes normally encountered is ¼ in. up to 8 in. in dia, and a fraction of an inch up to 6-8 in. in length.

MACHINABILITY RATINGS (Based on AISI B1112=100)

Aluminum Alloys (wrought)	
3003	Soft
2011	Excellent
2014	Average
2017	Average
2018	Average
2024	Average
6151	Soft
5052	Soft
5056	Average
6061	Soft
6063	Soft
7075	Average
Aluminum Alloys (cast)	
43	Soft
85	Soft
108	Soft
113	Average
122	Excellent
138	Average
142	Average
195	Average
212	Average
214	Average
220	Excellent
319	Soft
355	Soft
380	Soft
750	Excellent
Coppers	
Copper, 99.9%	40
Electrolytic Tough Pitch	40–50
Leaded Copper	160
Oxygen-Free Copper	40
Phosphorized Copper	40
Selenium Copper	180
Tellurium Phosphorized Coppers	180
Copper Alloys	
Aluminum Bronze (alpha), 92–95%	60–80
Copper Alloys (cont'd)	
Aluminum Bronze (duplex)	60–100
Architectural Bronze, 58%	180
Beryllium Copper, 97%	40
Cartridge Brass, 70%	60
Commercial Bronze, 90%	40
Forging Brass, 60%	160
Free Cutting Brass, 61.5%	200
Gilding Bronze, 95%	40
Gun Metal, Cast, 95.8%	60
High Leaded Brass, 62%	180
Leaded Commercial Bronze, 89%	180
Leaded Naval Brass, 60%	140
Leaded Nickel Silver, 46%	160
Leaded Phosphor Bronze (B_1)	100
Leaded Phosphor Bronze (B_2), 94%	200
Leaded Silicon Bronze, 95.6%	120
Low Brass, 80%	60
Low Leaded Brass, 64%	140
Manganese Bronze, 59%	60
Muntz Metal, 60%	80
Naval Brass, 60%	60
Nickel Silvers	40
Phosphor Bronze, 92% (Grades A, C, D, E)	40
Red Brass, 85%	60
Silicon Bronze, 95.8%	60
Irons	
Cast Iron Soft	80
Medium	65
Hard	50
Ingot Iron	50
Irons (cont'd)	
Malleable Iron Standard	120
Pearlitic	80
Wrought Iron	50
Magnesium Alloys (wrought)	500–2000
Nickel and Its Alloys	
Nickel	20
Nickel Alloys (rolled)	40–55
Monel (cast)	35
Monel (rolled)	40–55
Monel, K	40
Screw Machine Steels	
SAE 1120 (leaded)	140
SAE X1112	140
SAE 1112	100
SAE X1314	90–95
SAE X1315	90–95
SAE 1120	70–75
SAE X1335	70–75
SAE X1350	70–75
Carburizing Steels	
SAE X1020	50–65
SAE 1025	50–65
SAE 1020	50–65
SAE 1015	50–65
SAE 6120 (annealed)	45–50
SAE 6115	45–50
SAE 3115	45–50
SAE 4615 (annealed)	45–50
SAE 2315 (annealed)	45–50
SAE 3215	45–50
Heat Treating Steels	
SAE 1035	55–60
SAE 1040	55–60
Heat Treating Steels (cont'd)	
SAE 1045 (annealed)	55–60
SAE 4130 (annealed)	40–50
SAE 4140 (annealed)	40–50
SAE 3140 (annealed)	40–50
SAE 6135 (annealed)	40–50
SAE 6140 (annealed)	40–50
SAE 6150 (annealed)	40–50
SAE 1335 (annealed)	40–50
SAE 1350 (annealed)	30–40
SAE 2330 (annealed)	30–40
SAE 2345 (annealed)	30–40
SAE 3140	30–40
SAE 2345	30–40
SAE 52100 (annealed)	30–40
Stainless Steels	
Type 405	55
Type 406	50
Type 430	50
Type 442	60
Type 443	60
Type 446	65
Type 430-F	90
Type 403	50
Type 410	50
Type 414	60
Type 416	85
Type 420	50
Type 420-F	70
Type 431	54
Type 440	40
Type 501	70
Type 502	70
Type 302	35
Type 303	60
Type 304	45
Type 309	48
Type 316	46
Type 317	45
Type 321	50
Type 347	48
Zinc	200

Spinnings

ADAPTABILITY OF METALS TO SPINNING

Material ⬇	Shallow Spinning	Deep Spinning
Group 1—Aluminum and Its Alloys		
1100-O	1.00	1.00
3003-O	1.00	0.99
2024-O	0.65	0.45
5052-O	0.80	0.55
6061-O	0.90	0.80
Group 2—Copper and Its Alloys		
Copper (cold rolled, annealed)	1.00	1.00
Copper (hot rolled)	0.99	0.88
Yellow Brass	0.99	0.92
Cartridge Brass, 70%	0.99	0.92
Low Brass, 80%	0.96	0.89
Red Brass, 85%	0.90	0.83
Commercial Bronze, 90%	0.88	0.80
Gilding, 95%	0.85	0.75
Admiralty	0.82	0.70
Naval Brass	0.75	0.45
Muntz Metal	0.55	0.30
Phosphor Bronze A	0.85	0.40
Phosphor Bronze C	0.85	0.45
Cupro Nickel, 30%	0.95	0.65
Nickel Silver A	0.95	0.65
Silicon Bronze	0.94	0.60
Group 3—Carbon and Low Alloy Steels		
Cold Rolled (deep drawing quality)	1.00	1.00
Vitreous Enameling (deep drawing and spinning quality)	1.00	0.95
Cold Rolled (standard)	1.00	0.92
Hot Rolled (pickled and oiled)	1.00	0.92
Hot Rolled (low carbon)	0.90	0.55
Hot Rolled (copper-bearing)	0.88	0.51
Lead Coated (long Terne)	1.00	*
Galvannealed	1.00	*
Galvanized	0.90	*
High Strength	0.45	0.15
Carbon (0.40% and above)	0.25	0.10
Group 4—Stainless Steels		
Type 302	0.98	0.60
Type 304	0.98	0.90
Type 305 (free-spinning)	1.00	1.00
Type 309S	0.80	0.45
Type 316	0.90	0.60
Type 321	0.85	0.50
Type 347	0.90	0.50
Type 430	0.90	0.50
Group 5—Nickel and Its Alloys		
Monel (spinning quality)	1.00	0.90
Monel (special cold rolled, soft temper)	1.00	0.85
Inconel	0.90	0.70
Nickel (low carbon)	1.00	1.00
Nickel	1.00	0.92
Multimet N-155	0.90	0.50
Hastelloy A	0.75	0.35
Hastelloy B	0.70	0.30
Hastelloy C	0.50	0.10
Group 6—Miscellaneous Metals		
Lead	0.96	0.90
Pewter	1.00	0.99
Zinc	1.00	1.00
Tantalum	0.86	0.45
Magnesium	0.80	0.45
Molybdenum	0.55	0.15

*Impractical—coating flakes off.

MATERIALS

Most metals, with the exception of magnesium and molybdenum, can be cold spun. Metals such as gold, silver, platinum, kovar, invar and ilium can be spun but require special handling.

The adaptability of metals to the spinning process is rated in the chart given above. The unit 1.00 is assigned to the type of material in each group that lends itself most readily to cold spinning. The lower the index, the higher the cost. These figures will vary slightly with contour, gage and size.

This analysis applies to manual metal spinning by the cold method. Where quantities warrant special automatic spinning setups, or where existing automatic setups can be used, difficult-to-form metals can be deep spun readily. The deep spinning ratings in the table do not apply under these conditions.

Mechanical Tubing

TOLERANCES FOR ALUMINUM ALLOY TUBING—SEAMLESS[a]

Diameter, in. ↓	Diameter Tolerance, in.		Wall Thickness, in. ↓	Wall Thickness Tolerance, in.	
	Drawn	Extruded		Drawn	Extruded
0.125– 0.500	0.003	—	To 0.062 Incl	—	0.007–0.010
0.501– 1.000	0.004	0.010	0.010–0.035	0.002	—
0.001– 2.000	0.005	0.012	0.036–0.049	0.003	—
2.001– 3.000	0.006	—	0.050–0.120	0.004	—
2.000– 3.999	—	0.015	0.063–0.124	—	0.008–0.015
3.001– 5.000	0.008	—	0.121–0.203	0.005	—
4.000– 5.999	—	0.025	0.125–0.249	—	0.009–0.020
5.001– 6.000	0.010	—	0.204–0.300	0.008	—
6.001– 8.000	0.015	0.035	0.250–0.374	—	0.011–0.025
8.001–10.000	0.020	0.045	0.301–0.375	0.012	—
10.000–12.000	0.025	0.055	0.375–0.499	—	0.015–0.035
12.000–12.250	—	0.065	0.376–0.500	0.032	—
			0.500–0.749	—	0.020–0.045
			0.750–0.999	—	0.035–0.055
			1.000–1.499	—	0.045–0.065

[a]All values are ±.

TOLERANCES FOR STEEL TUBING—SEAMLESS[a]

Size (o.d.), in. ↓	O.D., in.	I.D., in.
3/16 to 1/2 Excl[b,c]	+0.004	—
1/2 to 1 1/2 Excl[b,c,d]	+0.005	−0.005
1 1/2 to 3 1/2 Excl[b,c,d]	+0.010	−0.010
3 1/2 to 5 1/2 Excl[b,c,d]	+0.015	−0.015, +0.005
5 1/2 to 8 Excl[e]	±0.030	±0.035
5 1/2 to 8 Excl[f]	±0.020	±0.025
5 1/2 to 8 Excl[g]	+0.030	−0.030, +0.015
8 to 10 3/4 Incl[e]	±0.045	±0.050
8 to 10 3/4 Incl[f]	±0.035	±0.040
8 to 10 3/4 Incl[g]	+0.045	−0.040, +0.015

[a]Round cold finished.
[b]For tubes with i.d. less than 50% of o.d. or with wall more than 25% of o.d., or with wall over 1 1/4 in., or weighing more than 90 lb per ft, which cannot be successfully drawn over a mandrel, i.d. may vary over or under by an amount equal to 10% of the wall. The wall may vary 12 1/2% over or under that specified.
[c]For tubes with i.d. less than 1/8 in. (or less than 5/8 in. when wall is more than 20% of o.d.), which cannot be successfully drawn over a mandrel, wall may vary 15% over or under that specified and i.d. will be governed by o.d. and wall variations.
[d]Tubing having a wall less than 3% of o.d. cannot be straightened properly without a certain amount of distortion. Consequently, such tubes, though having an average o.d. and i.d. within the tolerances shown, will require an ovality tolerance of 1/2% over or under nominal o.d. and i.d., this being in addition to the tolerances indicated.
[e]When wall is less than 5% of o.d., note "c" applies.
[f]When wall is from 5% to 7.5% of o.d.
[g]When wall is greater than 7.5% of o.d., note "a" applies.

TOLERANCES FOR STEEL TUBING—WELDED[a]

Size (o.d.), in.	Wall Thk (BWG)	Mandrel Swaged (standard tube)			Drawn over Mandrel[b]		
		O.D., in.[c]	I.D., in.[c]	Oval., in.	O.D., in.[c]	I.D., in.[c]	Oval., in.
1/4–3/8	16–22	0.003	0.008	0.003	0.002	0.005	0.003
	14	0.003	0.010	0.003	0.002	0.007	0.003
1/2–5/8	20–22	0.004	0.005	0.004	0.003	0.003	0.003
	16–18	0.004	0.005	0.004	0.002	0.002	0.003
	12–14	0.004	0.009	0.004	0.002	0.005	0.003
3/4–1 1/8	18–22	0.004	0.005	0.005	0.003	0.003	0.004
	14–16	0.004	0.005	0.005	0.003	0.003	0.004
	11–13	0.004	0.008	0.005	0.003	0.003	0.004
1 1/4–2	18–22	0.005	0.006	0.008	0.004	0.004	0.005
	14–16	0.005	0.006	0.006	0.003	0.003	0.005
	9–13	0.005	0.008	0.006	0.003	0.003	0.004
2 1/8–2 1/2	18–22	0.006	0.007	0.010	0.004	0.004	0.005
	14–16	0.006	0.007	0.008	0.004	0.004	0.005
	9–13	0.006	0.009	0.008	0.004	0.004	0.004
2 5/8–3	18–20	0.010	0.012	0.020	—	—	—
	14–16	0.008	0.010	0.015	0.006	0.006	0.008
	9–13	0.008	0.010	0.012	0.006	0.006	0.008
3 1/8–3 1/2	16–18	0.010	0.012	0.016	—	—	—
	9–14	0.008	0.012	0.014	—	—	—
3 5/8–4	14–16	0.010	0.014	0.018	—	—	—
	8–13	0.010	0.016	0.014	—	—	—
4 1/8–5	14–16	0.020	0.020	0.025	—	—	—
	8–13	0.015	0.018	0.025	—	—	—

[a]Cold rolled carbon steel.
[b]O.d. up to 35% closer than standard; i.d. up to 40% closer than standard.
[c]All values are ±.

TOLERANCES FOR MAGNESIUM TUBING—SEAMLESS[a]

Diameter, in. ↓	Diameter Tolerance, in.[b]	Ovality Tolerance, in.[b]	Wall Thickness, in. ↓	Wall Thickness Tolerance, in.				
				To ¾ In. Incl	Over ¾ to 1¼ In. Incl	Over 1¼ to 3 In. Incl	Over 3 to 5 In. Incl	Over 5 to 7 In. Incl
To 0.500 Incl	0.008	0.008						
0.501–1.000	0.011	0.011						
1.001–2.000	0.015	0.015	To 0.049 Incl	0.007	0.008	0.009	—	—
2.001–3.000	0.018	0.018	0.050–0.120	0.007	0.010	0.012	0.015	—
3.001–4.000	0.023	0.023	0.121–0.203	0.008	0.012	0.015	0.018	0.025
4.001–5.000	0.027	0.027	0.204–0.300	—	0.014	0.020	0.025	0.031
5.001–6.000	0.031	0.031	0.301–0.375	—	0.016	0.025	0.035	0.045
6.001–7.000	0.037	0.037	0.376–0.500	—	0.018	0.035	0.047	0.055

[a]Round.
[b]Tolerances may be expressed as all plus or minus, in which case double the tolerance given in the table will be used. Unless otherwise indicated, magnesium round tubing will be supplied to the plus or minus tolerance.

TOLERANCES FOR NICKEL AND NICKEL ALLOY TUBING—SEAMLESS[a]

Size, in. ↓	Mean O.D., in.[d,e]	Mean I.D., in.[b,d,e]	Wall, %[b]
Monel, A Nickel			
<½ I.D.	+0.005, −0.000	[c]	12½
½ I.D.–1½ O.D., Incl	0.005	0.005	10
>1½ O.D. to 4½ O.D., Incl	0.010	0.010	10
>4½ O.D. to 6 O.D., Incl	0.015	0.015	12½
>6 O.D. to 7½ O.D., Incl	0.020	0.020	12½
>7½ O.D. to 8⅝ O.D., Incl	0.025	0.025	12½
Inconel, K Monel, Z Nickel			
<½ I.D.	0.005		15
½ I.D.–1½ O.D., Incl	0.0075	0.0075	10
>1½ O.D. to 3½ O.D., Incl	0.010	0.010	10
>3½ O.D. to 4½ O.D., Incl	0.015	0.015	10
>4½ O.D. to 6 O.D., Incl	0.020	0.020	12½

[a]Round cold drawn. All tolerances plus or minus, except where otherwise indicated. Tolerances given here are applicable only to two dimensions at a time.
[b]For all tubing in all tempers, with i.d. less than 50% of o.d., or with a wall more than 25% of o.d., which cannot be successfully drawn over a mandrel, i.d. may vary over or under by an amount equal to 10% of the wall, and the wall may vary 12½% over or under that specified.
[c]For tubes in all tempers, with i.d. less than ½ in. (or less than ⅝ in. when wall is more than 20% of the o.d.), which cannot be successfully drawn over a mandrel, i.d. will be governed by o.d. and wall variations.
[d]Tubes in all tempers having a wall less than 3% of o.d. cannot be straightened properly without a certain amount of distortion. Consequently, such tubes, though having average o.d. and i.d. within permissible variations shown, will have an ovality tolerance of 0.5% over and under the nominal o.d. and i.d., this being in addition to the tolerances indicated.
[e]Tubes furnished in soft annealed temper are apt to possess more or less ovality or out-of-roundness because of warpage in soft annealing, or because of subsequent straightening operations. Therefore soft annealed tubes will not be as close to i.d. or o.d. as the table indicates

TOLERANCES FOR COPPER AND COPPER ALLOY TUBE[a]—SEAMLESS

Size (o.d.), in. ↓	Mean Diameter, in.	
	Nonrefractory Alloys	Refractory Alloys
Up to ⅛, Incl	0.002	0.003 (i.d.), 0.0025 (o.d.)
>⅛ to ⅝, Incl	0.002	0.0025
>⅝ to 1, Incl	0.0025	0.003
>1 to 2, Incl	0.003	0.004
>2 to 3, Incl	0.004	0.005
>3 to 4, Incl	0.005	0.006
>4 to 5, Incl	0.006	0.008
>5 to 6, Incl	0.007	0.009
>6 to 8, Incl	0.008	0.010
>8 to 10, Incl	0.010	0.013

[a]Industry terminology favors "Commercial Tube" over "Mechanical Tubing." Tolerances apply to i.d. or o.d. except where otherwise indicated.

Welded and Brazed Parts

GENERAL

A wide range of thicknesses, sizes and shapes can be fabricated by welding. Welded parts and products vary from extremely delicate devices to huge, ponderous parts. Parts as thin as 1 mil and as thick as 20 in. have been welded commercially. The thicknesses that can be welded vary considerably from metal to metal, and also depend upon the welding process. Dissimilar thicknesses of metal can be joined by welding and brazing.

WELDABLE FORMS

Plate, sheet, strip. Plate and sheet stock are probably the most widely used forms for weldments. This is particularly true for medium and large sized structural parts. Flat stock in the common ferrous and nonferrous metals is available in a wide range of sizes and thicknesses. The common methods used in the fabrication of flat stock for weldments are shearing, flame cutting, blanking, bending, spinning, stamping and pressing.

Castings, forgings. Large and small castings and forgings are used extensively in weldments. They are often the best solution for parts whose size or shape makes a one-piece casting or forging too costly or impossible. They are also used extensively for intricately shaped parts where plate fabrication is not feasible.

Extrusions, tubing. Extrusions and tubing are frequently used in fabricating parts by welding. A countless number of extruded shapes are available in the light metals and copper alloys. Tubing of many sizes and shapes is available both in ferrous and nonferrous metals.

Rolled shapes. Standard and special rolled shapes are commonly used in design of weldments. The standard shapes, in particular, are readily available, are mass produced and are, therefore, relatively low in cost. Where sections can be used they often permit development of a part using a minimum of forming operations and a minimum of welding. Rolled shapes also can often add rigidity and reduce shrinkage and/or distortion.

TOLERANCES

The two principal factors influencing tolerances are distortion from the welding operation and the tolerances of the metal forms that make up the weldment. The tolerances on the various metal forms, such as flat stock, castings, forgings and rolled sections, are easily obtainable. But degree of welding distortion is a function of a great many things, and therefore exact values cannot be given. The following tolerances seem to be those most commonly achieved:

1. Small parts containing very little welding, ⅛ in.
2. Moderately large parts containing a small amount of welding, ¼ in.
3. Large structures containing moderate amounts of welding, ⅜ in.
4. Large, complicated structures, and structures containing large amounts of welding, ⅜ to ½ in.

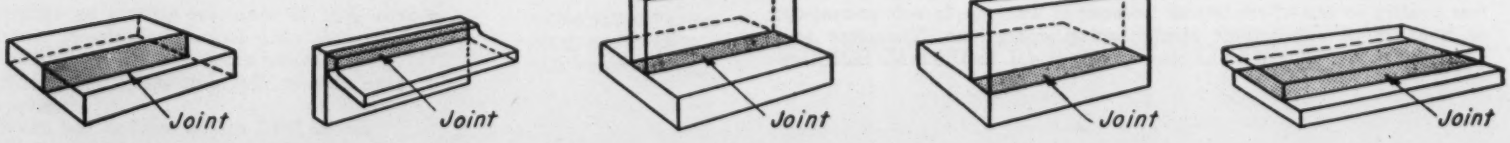
WELDABLE METALS

The table at the right is a general guide to the relative ease with which the common engineering metals and alloys can be welded or brazed. Weldability can be definitely indicated only when exact

JOINT DESIGN FOR VARIOUS WELDING METHODS *

Type of Joint →	Butt Joint		Lap Joint		Fillet Joint		Edge Joint	
	Light Section	Heavy Section	Light Section	Heavy Section	Light Section	Heavy Section	Light Section	Heavy Section
Shielded Metal Arc (coated electrode)	S	R	R	R	R	R	NR	R
Submerged Arc	S	R	S	R	S	R	NR	S
Atomic Hydrogen	R	S	S	S	S	R	R	S
Inert-Gas Tungsten Arc	R	S	R	S	R	S	R	S
Inert-Gas Metal Arc	NR	R	NR	R	NR	R	NR	S
Flash	NR	R	NA	NA	NA	NR	NA	NA
Spot	NA	NA	R	R	NA	NA	NA	NA
Seam	NA	NA	R	R	NA	NA	R	R
Gas (Oxyacetylene)	R	S	R	S	R	S	R	S
Brazing (furnace)	NR	NR	R	R	R	R	NA	NA
Brazing (torch)	S	S	R	R	R	R	S	S

*R—Recommended. S—Satisfactory. NR—Not Recommended. NA—Not Applicable. Light section: 0.005 to 0.125 in. Heavy section: ⅛ in. and over



Butt Weld | Edge Joint | Tee (Fillet) Joint | Corner (Fillet) Joint | Lap Joint

composition, heat treated condition, and a number of other variables are known. The following definitions apply to the weldability ratings used:

Readily weldable—widely and easily welded.

Weldable—can be welded, but special precautions (such as preheating or post heat treating) must usually be observed.

Difficult—can be welded if necessary, but only if special precautions are taken. Not recommended for quantity production.

WELDABILITY OF MATERIALS

Material ⬇	Arc Welding	Oxyacetylene Welding	Resistance Welding	Brazing
Low Carbon Steels (up to 0.30% C)	Readily weldable. Metal arc, submerged arc and atomic hydrogen most commonly used. Weldable by inert-gas arc	Readily weldable with welding rods of same composition or with nonferrous rods	Readily weldable by all resistance processes	Readily brazed using common brazing alloys
Medium Carbon Steels (0.30 to 0.45% C)	Weldable. As carbon increases, welding becomes more difficult	Weldable with rods of same composition or nonferrous type	Weldable. Flash and upset can be used over wide range of carbon content	Readily brazed using common brazing alloys
High Carbon Steels (0.50 to 0.80% C)	Difficult	Difficult. Seldom used	Difficult	Can be brazed using special techniques
Low Alloy Steels	Most hot rolled grades readily welded with metal arc. Submerged arc used on hot rolled and heat treated grades. Atomic hydrogen, and inert-gas arc restricted to the lighter gages	Hot rolled and heat treated grades readily weldable	Readily weldable. Seam and projection methods usually limited to hot rolled grades	Hot rolled grades readily brazed. Not generally used for heat treated grades where tensile strength over 100,000 psi required
Stainless Steels—Nickel-Chromium Types (300)	Readily weldable by metal arc, submerged arc, atomic hydrogen, and inert-gas arc methods. Where corrosion a factor, use low carbon or stabilized grades	Readily weldable in thin gages (20 gage), though thicker sections can be welded	Readily weldable. Close control of all welding factors required	Readily brazed with silver brazing alloys
Stainless Steels—Straight Chromium Types (400)	Weldable	Weldable in thin gages	Weldable. Susceptible to hardening	Brazed with silver and other brazing alloys
Cast Irons	Weldable. Metal arc OK where ductile weld not required. Inert-gas arc finds limited use	Readily weldable with cast iron rods. Braze welding suitable where weldment not subject to corrosion or thermal stresses	Seldom used. Can be flash welded	Difficult. Quality controlled cast irons and nickel-containing types more easily brazed
Cast Steels	Weldable with metal arc and submerged arc methods when carbon does not exceed 0.25%. Special precautions for >0.25% C	Weldable. Generally limited to thinner sections and ferritic grades. Braze welding using nonferrous rods also applicable	Mild, medium and some low alloy cast steels weldable by flash welding where air-hardening tendency not excessive	Readily brazed
Aluminum and Its Alloys	Readily weldable by inert-gas arc. Weldable by metal arc, carbon arc and atomic hydrogen. Some heat treatable alloys more difficult than non heat-treatable grades	Weldable in sections of about 0.040 to 1 in.	Readily weldable by spot, seam, upset and flash welding. Precision control necessary to produce consistent high quality welds	Most types can be brazed commercially
Magnesium and Its Alloys	Weldable by inert-gas arc process	M[1] alloy (1.5% Mn) sheet, extrusions and castings most suitable. Others less satisfactory	Alloys M[1] and AZ31X sheet and extrusions can be spot welded. Some use made of seam and flash welding	Commercial brazing limited to M[1] (1.5% Mn) alloy
Copper and Its Alloys	Weldable by carbon arc and inert-gas arc methods. More difficult with other arc processes	Weldable. Some lead-containing alloys are difficult. Method not common for phosphor bronze and aluminum bronze	Copper weldable by upset or modified flash upset methods. Brasses (except high lead brass) weld fairly well. Most bronzes weldable	Copper and high copper brasses readily brazed. Brazing of bronzes varies considerably with composition
Nickel and Its Alloys	Nickel, monel and Inconel readily weldable by all arc processes	Nickel, monel and Inconel weldable. Braze welding also used	Readily weldable. Inconel X difficult	Readily brazed
Titanium	Weldable by inert-gas arc methods	Not used	Weldable by spot and flash methods	Brazed with some difficulty
Tungsten, Molybdenum	Weldable by inert-gas arc and atomic hydrogen methods with proper precautions	Not used	Tungsten difficult; can be flash welded. Molybdenum can be spot, projection, seam and upset welded	Readily brazed

NEW DIMENSIONS IN DESIGN
NEW CONCEPTS OF ECONOMY

VERSATILE ACIPCO
Centrifugally Spun STEEL TUBES

In all types of industry, versatile Acipco centrifugally spun tubing is giving the design engineer greater freedom. Furnished with the exact combination of physical, chemical and metallurgical properties required by design, manufacturing and service conditions, high quality Acipco tubing helps create both new dimensions in design and new concepts of economy.

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AMERICAN CAST IRON PIPE CO.
Special Products Division
BIRMINGHAM 2, ALABAMA

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Austin-Hastings Co., Inc.
226 Binney St.
Cambridge 42, Mass.

Peter A. Frasse and Co., Inc.
17 Grand St.
New York 13, N.Y.

Lyman Tube & Bearings, Ltd.
920 Ste. Sophie Lane
Montreal 3, Canada

Vinson Steel & Aluminum Co.
4606 Singleton Blvd.
Dallas 7, Texas

J. M. Tull Metal & Supply Co.
285 Marietta St., N.W.
Atlanta, Ga.

C. A. Roberts Company
2401 Twenty-fifth Avenue
Franklin Park, Ill.

Strong, Carlisle & Hammond Co.
1392 W. Third St.
Cleveland 13, Ohio

Ducommun Metals & Supply Co.
4890 So. Alameda St.
Los Angeles 54, Calif.

For more information, turn to Reader Service card, circle No. 448

DIRECTORY
SECTION

Suppliers of Materials

Addresses of Suppliers

THE DIRECTORY

This Directory is designed to be a comprehensive and up-to-date source of suppliers of engineering materials, forms, finishes and closely related services. The listings were compiled from information received from more than 3000 manufacturers, from official information made available by trade associations, and from many other sources.

HOW TO USE THE DIRECTORY

The Directory consists of two sections. In the first, Section 9, the categories of materials, forms, finishes and related services are arranged alphabetically; suppliers in each category also are listed alphabetically. The many cross references make it easy to find any given category. In general, suppliers of basic or "mill" forms of materials, such as sheet, are listed under the particular material, whereas suppliers of "fabricated" forms, such as forgings, are listed under the form.

Key letters and numbers in parenthesis following names of suppliers provide additional information. Letters indicate the basic materials in which a supplier furnishes a particular fabricated form. For example, if you are looking for suppliers of magnesium sand castings, you will look for those suppliers of sand castings whose names are followed by the letter "D."

Similarly, numbers indicate the basic forms in which a supplier furnishes a particular material. For example, if you are looking for suppliers of cellulose acetate rod, you will look for those suppliers of cellulose acetate whose names are followed by the number "12."

The second part of the Directory, Section 10, contains a complete alphabetical list of suppliers and their addresses. To find the address of a division of a company, look up the name of the parent company (always given with the division name in Section 9). Further information on a particular supplier's product can often be found by consulting an advertisement in this issue. Advertires' names are bold faced, and the pages on which their advertisements appear are listed following their addresses in Section 10. Page numbers of advertisements are also given in the complete index to advertisers on page 429.

In compiling a directory of this nature it is impossible to avoid errors and omissions. We plan to constantly improve this directory in future editions and we will welcome corrections and suggestions. Please address them to Directory Editor, Materials in Design Engineering, 430 Park Ave., New York 22, N. Y.

MATERIALS

A Aluminum and its alloys
B Copper and its alloys
C Iron and its alloys (except steel)
D Magnesium and its alloys
E Nickel and its alloys
F Steels
G Titanium and its alloys
H Zinc and its alloys
J Thermoplastics
K Thermosetting plastics
L Elastomers

BASIC FORMS

1 Anodes
2 Bar
3 Billets
7 Foil
8 Ingot
9 Plate
10 Powder
12 Rod
13 Sheet
14 Strip
17 Base resins, polymers or gums
18 Laminating or casting resins
19 Fibers or filaments
20 Film
21 Foams (component materials or products)
22 Molding compounds
23 Tube, nonmetallic (except plastics or rubber)

The listings and other data included in this directory are compiled from sources believed by the publisher to be reliable. The publisher, however, does not represent or guarantee the accuracy of said listings and data, and no responsibility is assumed therefor.

Suppliers of Materials

ACETAL PLASTICS
du pont de Nemours, E. I. & Co., Inc. (17)

ACETATE (see Cellulose Acetate)

ACRYLATE RUBBER
(see Acrylic Rubber)

ACRYLIC PLASTICS
Ace Plastic Co. (12, 13, 14)
Adhesive Products Corp. (18)
American Hard Rubber Co. (13)
American Molding Powder & Chemical Co. (22)
American Products Mfg. Co., Inc. (20, 12, 13)
Anchor Plastics Co., Inc. (12, 14)
Auburn Plastic Engineering Co. (12, 13)
Bamberger, Claude P. Inc. (22)
Borden Co., Chemical Div. (17)
Cadillac Plastic & Chemical Co. (12, 13, 14)
Cast Optics Corp. (13)
Commercial Plastics & Supply Corp. (12, 13, 14)
du Pont de Nemours, E. I. & Co., Inc. (17, 18, 19, 22)
Dura Plastics of New York, Inc. (12, 13)
Eastman Chemical Products, Inc. (19)
Fry Plastics Co. (12, 13)
General Aniline & Film Corp. (13)
Gering Products, Inc. (22, 12, 13, 14)
Glass Laboratories, Inc. (12, 14)
H & R Industries (12, 13, 14)
Industrial Plastics Corp. (12, 14)
K S H Plastics, Inc. (12, 13, 14)
Luminous Resins, Inc. (22)
Midwest Plastic Products Co. (13, 14)
Muehlstein, H. & Co., Inc. (22, 17, 13)
Perfex Plastics, Inc. (12, 14)
Reed Plastics Corp. (22)
Rohm & Haas Co. (17, 22, 13)
Schwab Plastics Corp. (12, 14)
Snyder Mfg. Co., Inc. (13)
Southern Plastics Co. (20, 12 ,13, 14)
Westlake Plastics Co. (20, 12, 13, 14)
World Plastex (12, 13, 14)

ACRYLIC RUBBER
Adhesive Products Corp. (18)
American Hard Rubber Co. (12, 13, 14)
Borden Co., Chemical Div. (17)
Commercial Plastics & Supply Corp. (12, 13, 14)
Continental Rubber Works (12, 13, 14)
Goodrich, B. F. Chemical Co. (17, 18, 19, 22)
Roth Rubber Co. (13)
Southern Plastics Co. (12 ,13, 14)

ACRYLONITRILE-BUTADIENE RUBBER
Adhesive Products Corp. (18)
American Hard Rubber Co. (12, 13, 14)
Chicago Molded Products Corp., Campco Div., (13)
Continental Rubber Works (22, 12, 13, 14)
Firestone Tire & Rubber Co. (17)
Geauga Industries Co. (22, 12, 14)
Goodrich, B. F. Chemical Co. (17, 18, 21, 22)
Goodyear Tire & Rubber Co., Chemical Div. (17)
Goshen Rubber Co., Inc. (22)
Home Rubber Co. (22, 12, 13, 14)
Luzerne Rubber Co. (12, 13, 14)
Mid-States Rubber Products, Inc. (22, 13, 14)
Naugatuck Chemical Div., U.S. Rubber Co. (13)
Raybestos-Manhattan, Inc. (12, 13, 14)
Roth Rubber Co. (22, 13)
Rubatex Div., Great American Industries, Inc. (21)
Southern Plastics Co. (12, 13, 14)
Stockwell Rubber Co., Inc. (22, 12, 13, 14)
Technical Specialties Co. (14)
Vulcanized Rubber & Plastics Co. (22)
Westlake Plastics Co. (12, 13, 14)

ADHESIVES
Adhesive Products Corp. (J, K, L)
American Cyanamid Co., Plastics & Resins Div. (K)
American Hard Rubber Co. (J, K, L)
American Products Mfg. Co., Inc. (J, L)
Angier Adhesives Div., Interchemical Corp. (J, K, L)
Armstrong Cork Co. (J, K, L)
Armstrong Products Co. (K)
Atlas Mineral Products Co. (J, K, L)
Avondale Co. (J, K, L)
Barrett Div., Allied Chemical & Dye Corp. (K)
Belding Corticelli Industries (J, K, L)
Biggs, Carl H. Co., Inc. (J, K)
Bisonite Co., Inc. (K)
Borden Co., Chemical Div. (J, K)
Ciba Co., Inc. (K)
Cooper, Peter Corp. (J)
Dacar Chemical Products Co. (J, K, L)
Dennis Chemical Co. (J, L)
Dow Corning Corp. (K, L)
du Pont de Nemours, E. I. & Co., Inc. (J)
Eastman Chemical Products, Inc. (J)
Federal Adhesives Corp. (J, K, L)
Franklin Glue Co. (J)
General Electric Co., Silicone Products Dept. (J, K)
General Mills, Inc., Chemical Div. (J, K)
Goodyear Tire & Rubber Co. (L)
Haskelite Mfg. Corp. (J, K, L)
Houghton Laboratories Inc. (J)
Hughes Glue Co. (J, K, L)
Johns-Manville Corp., Dutch Brand Div. (J, K)
Lee Rubber & Tire Corp. (L)
Magic Iron Cement Co. (J)
Marblette Corp. (K)
Marbon Chemical Div., Borg-Warner Corp. (K)
Midland Adhesive & Chemical Corp. (J, K, L)
Minnesota Mining & Mfg. Co. (K)
Monsanto Chemical Co. (K)
National Casein Sales (J, K)
Ohio Adhesives Corp. (J, K, L)
Paisley Products, Inc., Div. of Morningstar, Nicol, Inc. (J, K, L)
Pierce & Stevens Chemical Corp. (J, K, L)
Polymer Chemical Co. (J, K, L)
Polymer Corp. (J)
Randolph Products Co. (J, K, L)
Raybestos-Manhattan, Inc. (J, K)
Ren Plastics, Inc. (K)
Rubber & Asbestos Corp. (J, K, L)
Schwartz Chemical Co., Inc. (J, K, L)
Shell Chemical Corp. (J)
Standard Insulation Co. (K)
Stockwell Rubber Co., Inc. (L)
Synco Resins, Inc. (J, K)
U B S Chemical Corp. (L)
U.S. Stoneware Co. (J, K)
Williamson Adhesives, Inc. (J, K, L)

ALKYD PLASTICS
American Cyanamid Co., Plastics & Resins Div. (17)
Archer-Daniels-Midland Co. (17)
Barrett Div., Allied Chemical & Dye Corp. (22)
Booty Resineers, Inc. (17)
General Electric Co., Insulating Materials Dept. (17)
Glaskyd, Inc. (22)
Hercules Powder Co. (17)
Reichhold Chemicals, Inc. (17)
Schenectady Varnish Co., Inc. (17)
Sherwin-Williams Co. (17)
Specialty Resins Co. (17)

ALUMINIDES (see Ceramics)

ALUMINIZED METALS
(see Precoated Metals)

ALUMINUM AND ITS ALLOYS
Alloys & Chemicals Mfg. Co. (8)
Alpha Metals, Inc. (7)
Aluminum Ltd. Sales, Inc. (3, 8)
Aluminum Co. of America (1, 2, 3, 7, 8, 9, 10, 12, 13, 14)
Aluminum Foils Co. (7)
American Silver Co., Inc. (7, 14)
Anaconda Aluminum Co. (8)
Apex Smelting Co. (3, 8, 12)
Aurora Refining Co. (8)
Belmont Smelting & Refining Works, Inc. (8, 10)
Bohn Aluminum & Brass Corp. (2, 12)
Both, O. A. Corp. (10)
Bridgeport Brass Co. (13)
Bridgeport Rolling Mills Co. (13, 14)
Cleveland Electro Metals Co. (8)
Cochran Foil Co. (7, 13)
Dixie Aluminum Corp. (2, 12)
Fairmount Aluminum Co. (9, 13, 14)
Federated Metals Div., American Smelting and Refining Co. (2, 8)
Frasse, Peter A. & Co., Inc. (2, 9, 12, 13, 14)
Fromson Orban Co., Inc. (9, 12, 13, 14)
Frontier Bronze Corp. (8)
General Smelting Co. (8)
Gold Leaf & Metallic Powders, Inc. (10)
Harvey Aluminum Div., Harvey Machine Co., Inc. (2, 3, 8, 12)
Himmel Bros. Co. (2)
Hokin Aluminum Co. (2, 12)

Hommel, O. Co. (10)
Jobbins, Wm. F. Inc. (8)
Kaiser Aluminum & Chemical Sales, Inc. (2, 3, 7, 8, 9, 12, 13)
Kirk, Morris P. & Son, Inc. (8)
Laminated Shim Co. (13)
Magna Mfg. Co., Inc. (10)
Malone Bronze Powder Works, Inc. (10)
Metals & Controls Corp., General Plate Div. (7)
Metals Disintegrating Co., Inc. (10)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (8)
Quaker State Metals Co. (13)
Reade Mfg. Co., Inc. (10)
Republic Foils & Metals, Inc. (7)
Revere Copper and Brass, Inc. (2, 7, 12, 13, 14)
Reynolds Metals Co. (2, 3, 7, 8, 9, 10, 12, 13, 14)
Rigidized Metals Corp. (13, 14)
Scovill Mfg. Co. (12, 13, 14)
Sel-Rex Corp. (1)
Sheet Aluminum Corp. (13)
Sonken-Galemba Corp. (3, 8)
Stranahan Foil Co., Inc. (7)
United Smelting & Aluminum Co., Inc. (13, 14)
U.S. Bronze Powder Works, Inc. (10)
U.S. Extrusions Corp. (12)
U.S. Reduction Co. (8)
Utility Mfg Co. (12)
Vacuum Metals Corp., Div. of Crucible Steel Co. of America (2, 3, 8, 9, 13, 14)
Werner, R. D. Co., Inc. (12)
White Metal Rolling & Stamping Corp. (13, 8)
Whitehead Metal Products Co., Inc. (9, 12, 13, 14)

ALUMINUM BRONZE (see Copper)

ANODES (see specific metal)

ANODIZERS
Acme Plating Co.
Aluminum Finishing Corp.
American Emblem Co., Inc.
B & T Metals Co.
Briggs-Shaffner Co.
Chicago Thrift-Etching Corp.
Colonial Alloys Co.
Edna Lite Optical Co., Inc.
Engineering Products & Specialties Inc.
Industrial Chromium Corp.
Leed, H. A. Co.
Metal Finishers, Inc.
Modern Plating Corp.
National Aluminum Co.
Reynolds Metals Co.

ASBESTOS
American Asbestos Textile Corp.
Asbestos Corp. of America
Asbestos Textile Co., Inc.
Carolina Asbestos Co.
Connell Asbestos Mfg. Co.
Johns-Manville Corp.
Keasby & Mattison Co.
Philadelphia Asbestos Corp.
Raybestos-Manhattan, Inc.
Standard Asbestos Mfg. Co.
Vermont Asbestos Mines

BAR (see specific metal)

BERYLLIUM
American Silver Co., Inc. (7, 14)
Belmont Smelting & Refining Works, Inc. (8, 10)
Beryllium Copper Supply Co. (12, 14)
Beryllium Corp. (2, 3, 8, 10)
Brush Beryllium Co. (2, 3, 7, 8, 9, 10, 12, 13, 14)
General Plate Div., Metals & Controls Corp. (7)
Hussey, C. G. & Co., Div. of Copper Range Co. (10)
Riverside-Alloy Metal Div., H. K. Porter Co., Inc. (2, 12, 13, 14)
Sel-Rex Corp. (1)

BERYLLIUM COPPER (see Copper)

BILLETS (see specific metal)

BISMUTH AND ITS ALLOYS
Alpha Metals, Inc. (2, 3, 7, 12, 13, 14)
American Metal Co., Ltd. (2, 8)
Belmont Smelting & Refining Works, Inc. (2, 8, 10)
Cerro de Pasco Sales Corp. (8)
Division Lead Co. (2)
Federated Metals Div., American Smelting and Refining Co. (2, 8)
Metals Disintegrating Co., Inc. (10)
Peerless Alloy Co. (2, 8)
Republic Metals Co., Inc. (2, 8, 14)
River Smelting & Refining Co. (8)
Sel-Rex Corp. (1)
U.S. Smelting, Refining & Mining Co. (12, 8)

BORIDES (see Ceramics)

BRASS (see Copper)

BRONZE (see Copper)

BUNA N RUBBER (see Acrylonitrile-Butadiene Rubber)

BUTYL RUBBER
(see Isoprene-Isobutylene Rubber)

BUTYRATE
(see Cellulose Acetate Butyrate)

CADMIUM
Alpha Metals, Inc. (2, 7, 12, 13, 14)
American Metal Co., Ltd. (8)
American Zinc Sales Co. (1, 8, 9)
Belmont Smelting & Refining Works, Inc. (1, 2, 8, 10)
Bunker Hill Co., Sales & Fabrication Div. (1)
Division Lead Co. (7, 13)
du Pont de Nemours, E. I. & Co., Inc. (1, 2)
Eagle-Picher Co. (3)
Federated Metals Div., American Smelting and Refining Co. (1, 3, 8)
Fox Products Co. (1)
Hardy, Charles, Inc. (10)
McGean Chemical Co. (1)
Metals Disintegrating Co., Inc. (10)
New Jersey Zinc Co. (1, 12)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (7, 8)
Republic Metals Co., Inc. (1, 2, 8)
St. Joseph Lead Co. (3)
Sel-Rex Corp. (1)
U.S. Smelting, Refining & Mining Co. (8)

CARBIDES (see Ceramics)

CARBON, GRAPHITE (incl parts; no key indicates custom parts only)
Black Bear Co., Inc. (10)
Blaco Mfg. Co. (10)
Dixon, Joseph Crucible Co. (9, 10, 12)
Graphite Metallizing Corp.
Graphite Specialties Corp. (12)
Henrite Products Corp.
Hofford Varnish Co., Inc.
Industrial Tectonics, Inc.
Markal Co. (9)
Morganite, Inc.
National Carbon Co. (9, 10, 12, 23)
Ohio Carbon Co. (9, 12)
Pure Carbon Co., Inc. (4, 5, 12)
Speer Carbon Co.
Stackpole Carbon Co. (12)
Standard Asbestos Mfg. Co. (19, 13, 23)
United Carbon Products Co. (9, 10, 12, 23)
U.S. Graphite Co., Div. of Wickes Corp. (9, 12, 13)

CASTING RESINS
(see specific plastic or rubber)

CASTINGS, CENTRIFUGAL
All Metals Precision Casting Corp. (A, B, F)
Allegheny Ludlum Steel Corp. (F)
Alloy Precision Castings Co. (A, B, C, D, E)
American Brake Shoe Co. (A, B, H)
American Cast Iron Pipe Co. (C, F)
Ampco Metal, Inc. (B)
Baldwin-Lima-Hamilton Corp. (A, B E)
Buckeye Brass & Mfg. Co. (A, B)
Bunting Brass and Bronze Co. (B)
Calorizing Co. (E, F)
Centrifugal Casting Machine Co. (A, B)
Centrifugally Cast Products Div., Shenango Furnace Co. (B, C, E)
Centr-O-Cast Engineering Co. (A)
Cooper Alloy Corp. (A)
Curtiss-Wright Corp. (F)
Cyril Bath Co. (F)
Dayton Foundry (C)
Duralloy Co. (F)
Electric Steel Foundry Co. (E, F, G)
Florence Pipe Foundry & Machine Co. (C)
General Alloys Co. (E, F)
Hughes Tool Co. (F)
International Nickel Co., Inc. (E)
Janney Cylinder Co. (A, B, C, E, F)
Johnson Bronze Co. (B)
Lebanon Steel Foundry (F)
McCarter Iron Works Inc. (C, F)
Metal Goods Corp. (A, B, C, E, F)
Milwaukee Aluminum & Brass Foundry (A, B)
Ohio Steel Foundry Co. (E)
Olds Alloys Co. (A, B)
Precision Metalsmiths, Inc. (A, B, E, F)
Sandusky Foundry and Machine Co. (B, E, F)
True Alloys, Inc. (A, B, H)
U.S. Pipe and Foundry Co. (C, F)
Utica Drop Forge & Tool Co. (E, F)
Winters Foundry & Machine Co., Inc. (A, B)

CASTINGS, DIE
Able Tool & Engineering Co. (A, H)
Accurate Metal Weather Strip Co., Inc. (H)
Admiral Die Castings Div., Portable Electric Tools, Inc. (A, H)
Advance Tool & Die Casting Co. (A, H)
Aluminum Co. of America (A, D)
American Aluminum Casting Co. (A)
American Crucible Products Co. (B)
American Foundries Co. (C)
Anchor Metal Co., Inc. (H)
Auel Industries (H)
Auld, D. L. Co. (A, H)
Aurora Metal Co. (B)
Badger Die Casting Co. (A)
Bendix Aviation Corp. (A, D)
Centrifugal Casting Machine Co. (A)
Chicago White Metal Casting, Inc. (A, H)
Cincinnati Foundry Co. (C)
Comet Metal Products Co., Inc. (H)
Conneaut Die Casting Co. (A, H)
Dayton Bronze Bearing Co. (A, H)
Diecast Corp. (A, H)

Doehler-Jarvis Corp., Div. of National Lead Co. (A, B, D, H)
Dollin Corp. (A, H)
Dow Chemical Co. (D)
Duane Specialties, Ltd. (H)
Du-Wel Metal Products Inc. (A, H)
Federal Die Casting Co. (A)
Foster Aluminum Alloy Products Corp. (A)
Grammes, L. F. & Sons, Inc. (H)
Grand Rapids Brass Co. (H)
Grey, C. M. Industries Inc. (A, H)
Gries Reproducer Corp. (H)
Hamilton Die Cast, Inc. (A, H)
Hampden Brass & Aluminum Co. (A, H)
Hardy Mfg. Corp. (H)
Harsco Corp., Precision Castings Div.
Harvey Aluminum Div., Harvey Machine Co., Inc. (A, H)
Harvill Corp. (A, D, H)
Hercules Fastener Co. (H)
Hilfinger Corp. (H)
Hoover Co. (A, H)
Kent Castings Corp. (H)
King-Seeley Corp. (H)
Krone, Paul Die Casting Co. (A, H)
La France Precision Casting Co. (H)
Lester Castings, Inc. (A, H)
Litemetal Dicast Inc. (D)
Littlestown Hardware & Foundry Co. Inc. (A)
Livingston-Tyler Products (H)
Madison-Kipp Corp. (A)
Magline, Inc. (A, D)
Milwaukee Die Casting Co. (A, H)
Model Brass Co., Inc. (A, B)
Monarch Aluminum Mfg. Co. (A, H)
Monarch Tool & Mfg. Co. (H)
Mt. Vernon Die Casting Corp. (A, H)
New Products Corp. (A, D)
Newton-New Haven Co. (A, H)
Norgren-Stemac, Inc. (H)
Paramount Die Casting Co. (A, D, H)
Parker White Metal Co. (A, H)
Phoenix Die Casting Co. (A, H)
Pittsburgh Die & Casting Co. (A, H)
Rupert Diecasting Co. (A, H)
St. Louis Diecasting Corp. (A, H)
St. Marys Foundry Co. (C)
Sargent & Greenleaf, Inc. (A, H)
Schilling Bronze Co. (A)
Schneider Bowman Co., Inc. (C)
Sterling Die Casting Co. (A, H)
Stuart Foundry Co. (C)
Superior Die Casting Co. (A, B)
Titan Metal Mfg. Co. (B)
Twin City Die Castings Co. (A, H)
Veeder-Root, Inc. (H)
Vulcan Rail & Construction Co. (A, C, F)
Weber-Knapp Co. (A)
West Irving Die Casting Co. (A)

CASTINGS, INVESTMENT

All Metals Precision Casting Corp. (A, B, F)
Alloy Precision Castings Co. (A, B, C, D, E, F)
Arwood Precision Castings Corp. (A, B, D, F)
Austenal, Inc. (C, E, F)
Bone Engineering Corp. (A, B, C, D, E, F, G, H)
Buckeye Brass & Mfg. Co. (B, C, F)
Budd-Stanley Co., Inc. (A, B, D, E, G, H)
Casting Engineers, Inc. (A, B, C, E, F)
Centrifugal Casting Co. (A B, D, E, G, H)
Chrysler Corp. (A, B, C, D, E, F, G, H)
Crucible Steel Co. of America (F)
Eaton Mfg. Co., Foundry Div. (C)
Electronicast, Div. of Nilsen Mfg. Co. (A, B, C, D, E, F, G, H)
Engineered Precision Casting Co. (A, B, C, E, F)
General Electric Co., Foundry Dept. (A, B, C, D, E, F, G, H)
Gray-Syracuse, Inc. (A, B, C, E, F)
Harcast Co. (A, B, C, E, F)
Hawkridge Bros. Co. (A, B, C, D, E, F, G, H)
Hitchiner Mfg. Co., Inc. (A, B, C, E, F)
Howard Foundry Co. (A, B, C, E, F, G)
Illinois Precise Casting Co. (A, C, D, E, F, G, H)
International Nickel Co., Inc. (E)
Investment Casting Co. (A, B, C, E, F)
Jelrus Precision Casting Corp. (A, B, C, D, E, F, G, H)
Kolcast Industries, Inc. (A, B, C, D, E, F, G, H)
Lawrence Laboratory (A, B, C, D, E, F, G, H)
Loeffler, J. M. Co., Machine & Brass Works (B)
Meehanite Metal Corp. (C)
Metal Goods Corp. (E, F)
Midwest Foundry Co. (C, F)
Misco Precision Casting Co. (A, B, C, D, E, F, G, H)
Precision Castparts Co. (A, B, C, D, E, F, G, H)
Precision Founders, Inc. (A, B, C, D, E, F, G, H)
Precision Metalsmiths, Inc. (A, B, E, F)
Rolle Mfg. Corp. (A, D)
Thompson, K. W. Tool Co. (A, B, C, D, E, F, G, H)
York Castings, Inc. (A, B, C, D, E, F, G, H)
Z & H Mfg. Co. (A, B, C, D, E, F, G, H)

CASTINGS, NONMETALLIC
(plastics and rubber)

Ace Plastic Co. (K)
Acushnet Process Co. (L)
Auburn Plastic Engineering (J)
Biggs, Carl H. Co., Inc. (J, K)
Boonton Molding Co. (J, K, L)
Cadillac Plastic & Chemical Co. (J)
Campro Co. (J)
Cast Optics Corp. (J, K)
Conneaut Rubber and Plastics Co. (J)
Disogrin Industries, Inc. (L)
Douglas & Sturgess (K, L)
Eby, Hugh H. Co. (J, K)
Eljay Corp. (K)
General Mills, Inc., Chemical Div. (J, K)
Grimes Mfg. Co., Plastic Research Products (K)
Hays Mfg. Co. (K)
Kerr, R. W. Plastic Co. (J, K, L)
Kurz-Kasch, Inc. (K)
Marblette Corp. (K)
Mechanical Rubber Products Co. (K)
Minnesota Rubber and Gasket Co. (J, L)
New England Tape Co., Inc. (K)
Pyrosil, Inc. (K)
Ren Plastics, Inc. (K)
Robot Devices Inc. (K)
Sewell Mfg. Co. (K)
Sierra Electronic Corp. (J)

CASTINGS, PERMANENT MOLD

A C F Industries, Inc. (D)
Acme Aluminum Foundry Co. (A)
Advance Aluminum Castings Corp. (A)
Aluminum Casting & Engineering Co. (A, H)
Aluminum Co. of America (A, D)
Aluminum Industries Inc. (A)
Aluminum Permanent Mold Co. (A)
Aluminum-Alloy Casting Co. (A)
American Aluminum Casting Co. (A)
American Brake Shoe Co. (A, B, H)
Apex Steel Corp., Ltd. (F)
Baldt Anchor, Chain & Forge Div., Boston Metals Co. (A, B)
Baldwin-Lima-Hamilton Corp. (A, B, E)
Bendix Aviation Corp. (A, D)
Bohn Aluminum & Brass Corp. (A)
Briggs-Shaffner Co. (A)
Bronze & Steel Die Casting Co. (A, B)
Buckeye Brass & Mfg. Co. (A, B)
Bunting Brass and Bronze Co. (B)
Calumet Div., Calumet & Hecla, Inc. (C)
Centrifugal Casting Machine Co. (A)
Centr-O-Cast Engineering Co. (A)
Cochrane Foundry, Inc. (A, B, H)
Crucible Steel Co. of America (F)
Derby Castings Co. (A)
Dirilyte Co. of America, Inc. (B)
Dixie Bronze Co. (B)
Dostal Foundry & Machine Co. (C)
Dow Chemical Co. (D)
Enterprise Wheel & Car Corp. (A)
Est Co., Inc. (A, D)
Exalco Mfg. Co. (A)
Fairfield Aluminum Castings Co. (A)
Fischer Casting Co., Inc.
Hampden Brass & Aluminum Co. (A)
Harvill Corp. (A, D)
Howard Foundry Co. (A)
General Aluminum Mfg. Co. (A, D)
Gillett & Eaton, Inc. (A)
Johnson Bronze Co. (B)
Lebanon Steel Foundry (F)
Light Metals, Inc. (A, D)
Littlestown Hardware & Foundry Co., Inc. (A)
Magline, Inc. (D)
Mansfield Brass & Aluminum Corp. (A)
Marshall Car Wheel & Foundry Co., Inc. (C)
Meehanite Metal Corp. (C)
Metal Mold Magnesium Corp. (D)
Meta-Mold Aluminum Co. (A)
Monarch Aluminum Mfg. Co. (A)
Morse, Fred W. Co. (A, H)
National Aluminum Mfg. Co. (A)
Oregon Metallurgical Corp. (G)
Parker, Charles Co. (A, H)
Permold Co. (A)
Rolle Mfg. Corp. (A, D)
Schilling Bronze Co. (A)
Schmeller Aluminum Foundry Co. (A)
Skookum Co., Inc. (F)
Standard Magnesium Corp. (D)
Sterling Aluminum Products, Inc. (A)
Texas Foundries, Inc. (C, F)
Thompson Products, Inc. (A)
True Alloys, Inc. (A, B, H)
Universal Castings Corp. (A, B)
Vulcan Rail & Construction Co. (A, C)
Waterman Industries, Inc. (A)
Wellman Bronze and Aluminum Co. (A, D)
Williams, A. C. Co. (D)
Winters Foundry & Machine Co., Inc. (A)
Wisconsin Aluminum Foundry Co., Inc. (A)

CASTINGS, PLASTER MOLD

All Metals Precision Casting Corp. (A, B)
Aluminum Co. of America (A, D)
Atlantic Casting & Engineering Corp. (A)
Bean, Morris & Co. (A)
Bendix Aviation Corp. (A, D)
Curtiss-Wright Corp. (F)
Derby Castings Co. (A)
Hampden Brass & Aluminum Co. (A)
Lebanon Steel Foundry (F)
Loeffler, J. M. Co., Machine & Brass Works (B)
Ohio Precision Castings, Inc. (A, B, E, H)
Ross-Meehan Foundries (C, F)
Schilling Bronze Co. (A)
Schneider Bowman Co., Inc. (C)
Searjeant Metal Products Inc. (A, C)
True Alloys, Inc. (A, B, H)
Universal Castings Corp. (A, B)
Wayne Foundry & Stamping Co. (H)
Western Iron & Foundry Co., Inc. (C)

CASTINGS, SAND

ABCO Aluminum & Brass Works (A, B, E)
Acco Malleable Casting Div., American Chain & Cable Co., Inc. (C)
Acco Steel Casting Div., American Chain & Cable Co., Inc. (F)
Acme Aluminum Foundry Co. (A)

Bold face indicates supplier advertises product in this issue

Suppliers of Materials

Aelco Brass Foundry (A, B, E, F)
Albany Car Wheel Co., Inc. (C)
Albert Lea Foundry Co. (C)
Albion Malleable Iron Co. (C)
Alcasco Foundry (A, B)
Allegheny Foundry Co. (C)
Allegheny Ludlum Steel Corp. (F)
Allied Steel Casting Co. (F)
Alloy Cast Steel Co. (F)
Alloy Steel Casting Co. (F)
Almont Mfg. Co. (C)
Aluminum-Alloy Casting Co. (A)
Aluminum Casting & Engineering Co. (A, H)
Aluminum Co. of America (A, D)
Aluminum Industries, Inc. (A)
Aluminum Permanent Mold Co. (A)
Amalgamated Steel Corp. (F)
American Aluminum Casting Co. (A)
American Brake Shoe Co. (A, B, H)
American Cast Iron Pipe Co. (C, F)
American Crucible Products Co. (B)
American Foundries Co. (C)
American Laundry Machinery Co. (C)
American Light Alloys, Inc. (D)
American Manganese Steel Div., American Brake Shoe Co. (F)
American Metal Co., Ltd. (B)
American Sanitary Mfg. Co. (B)
American Steel Foundries (F)
Ampco Metal, Inc. (B)
Apex Steel Corp., Ltd. (F)
Arkansas Foundry Co. (A, C)
Arneson Foundry Co. (C, F)
Arzt, T. L. Foundry Co. (C)
Atlantic Foundry Co. (C, F)
Atlantic Steel Castings Co. (F)
Atlas Brass Foundry (B)
Atlas Foundry Co. (C)
Atlas Foundry & Machine Co. (C, F)
Banner Iron Works (C)
Barnard Foundry Co., Inc. (B)
Barnett Foundry & Machine Co. (C)
Bavohr, Carl Co. (A, B, H)
Baxter Foundry & Machine Works, Inc. (A, C)
Bay City Electric Steel Casting Co. (F)
Bay State Tool & Machine Co. (F)
Bean, Morris & Co. (C)
Beaver Valley Alloy Foundry Co. (F)
Belcher Malleable Iron Co. (C)
Belle City Malleable Iron Co. (C)
Bendix Aviation Corp. (A, D)
Bethlehem Steel Co. (C, F)
Black-Clawson Co. (C)
Blackmer Pump Co. (C)
Bohn Aluminum & Brass Corp. (A)
Bonnot Co. (C)
Briggs-Shaffner Co. (A, C)
Brinkerhoff Brass & Bronze Works, Inc. (A, B, E, F)
Bruce Foundry and Mfg. Co. (C)
Buckeye Iron & Brass Works (A, B)
Budd Foundries Refractories (A, C)
Bunting Brass & Bronze Co. (B)
Butler Engine & Foundry Co., Inc. (A, B, C)
Cadillac Malleable Iron Co. (C)
Calorizing Co. (E, F)
Calumet Div., Calumet & Hecla, Inc. (C)
Calumet Steel Castings Corp. (F)
Campbell, Wyant & Cannon Foundry Co., Div. of Textron Inc. (C, F)
Carondelet Foundry Co. (C, F)
Casting Service Corp. of Michigan (C)
Chambersburg Engineering Co. (C)
Chase Brass & Copper Co. (B)
Chattanooga Aluminum Foundry (A)
Chicago Aluminum Castings (A)
Chicago Hardware Foundry Co. (A, B, C)
Chicago Malleable Castings Co. (C)
Cincinnati Foundry Co. (C)
Clarksville Foundry & Machine Works (A, C)
Cleveland Foundry & Mfg. Co., Inc. (C)
Clinton Metal Products Co. (A)
Cochrane Foundry, Inc. (A, B, H)
Columbian Bronze Corp. (A, B, C)
Columbiana Pump Co. (C)
Compton Foundry (C)
Continental Gin Co. (C)
Cooper Alloy Corp. (F)
Cooper-Bessemer Corp. (C)
Crawford & Doherty Foundry Co. (C)
Crown Non-Ferrous Foundry Inc. (A, B, E)
Crucible Steel Casting Co. (F)
Crucible Steel Co. of America (F)
Curtiss-Wright Corp. (F)
Dalton Foundries, Inc. (C)
Dayton Bronze Bearing Co. (A, B)
Dayton Foundry (C)
De Sanno Foundry & Machine Co. (A, B)
Decrow Engineering Corp. (A, B)
Derby Castings Co. (A, B)
Detroit Magnesium Castings Co. (D)
Dirilyte Co. of America, Inc. (B)
Dixie Bronze Co. (A, B)
Dow Chemical Co. (D)
Duluth Brass Works Co. (A, B)
Duralloy Co. (F)
East Birmingham Bronze Foundry Co. (A, B, H)
Eastern Malleable Iron Co. (C, F)
Elchinger, Charles F. (A, B)
Electric Materials Co. (B)
Electric Steel Foundry (C, E, F)
Electron Corp. (C)
Elkhart Iron Works (C)
Empire Pattern & Foundry Co. (A, B, C)
Enterprise Wheel & Car Corp. (A, C)
Erie Bronze Co. (A, B)
Eureka Electric Products Co. (A, B)
Fahralloy Co. (F)
Fairfield Aluminum Castings Co. (A)
Fischer Casting Co., Inc. (A)
Flood City Brass & Electric Co. (B)
Florence Pipe Foundry & Machine Co. (C)
Florin Foundry & Mfg. Co. (C)
Frederick Iron & Steel, Inc. (C)
Frontier Bronze Corp. (A, B, E)
Fulton Foundry & Machines Co., Inc. (C)
Gale Mfg. Co. (C)
Gartland Haswell Foundry Co. (C)
General Alloys Co. (E, F)
General Foundry & Mfg. Co. (C)
General Malleable Corp. (C)
General Motors Corp., Central Foundry Div. (C)
Georgia Iron Works (C)
Gibson & Kirk Co. (A, B, E)
Gilbert Brass Foundry Co. (A, B)
Gillett & Eaton, Inc. (A, C)
Glover Machine Works (F)
Gluntz Brass & Aluminum Foundry Co. (A, B, H)
Gowanda Furnaces, Inc. (C)
Grafton Foundry Co. (C)
Graham, James Co. (B)
Greenlee Foundry Co. (C)
Grimm Foundry Co., Inc. (C, F)
Gunite Foundries Corp. (C, F)
H & H Foundry Machine Co. (C)
Hamilton Foundry & Machine Co. (C)
Hampden Brass & Aluminum Co. (A, B, F)
Hardinge Mfg. Co. (C)
Helmick Foundry-Machine Co. (C)
Hewitt, John Foundry Co. (A, B, C)
Hills-McCanna Co. (D)
Hobbs, Clinton E. Co. (A, B, C)
Hodgson Foundry Co. (A, B)
Hoffman Bronze & Aluminum Casting Co. (A, B)
Homestead Valve Mfg. Co. (A, B, C, E)
Howard Foundry Co. (A, B, C, D, E, F)
Illinois Iron & Bolt Co. (A, E)
Independence Stove & Mfg. Co. (C)
Indiana Brass Co., Inc. (B)
Industrial-Ferguson Foundry Corp. (A, B, E, H)
International Nickel Co., Inc. (E)
Iowa Malleable Iron Co. (C)
Irwin Foundry and Mine Car Co., Industrial and Furnace Car Div. (C)
Jamestown Malleable Iron Corp. (C)
Johnson Bronze (B)
Johnstone Foundries, Inc. (C)
Kanawha Mfg. Co. (C)
Kansas City Hay Press Co. (C)
Kay-Brunner Steel Products, Inc. (F)
Keen Foundry Co., Inc. (C)
Kelly Foundry Co. (C)
King-Seeley Corp., Central Specialty Div. (C)
Kingsport Foundry & Mfg. Corp. (A, B, C, E)
Klinzing, A. F. Co., Inc. (C)
Koehring Co. (C)
Kutztown Foundry & Machine Corp. (C)
L F M Mfg. Co., Inc. (C, F)
La Porte Foundry Co. (A, C)
Laconia Malleable Iron Co. (C)
Lake Erie Foundry Co. (C)
Lakeside Bronze Inc. (A, B)
Langsenkamp-Wheeler Brass Works Inc. (A, B)
Laragy P. Iron Foundry, Inc. (C)
Lattimer Foundry and Machine Co. (A)
Lawrence Copper & Bronze Co. (B)
Lebanon Steel Foundry (F)
Lectromelt Casting (A, C, F)
Lee Bros. Foundry Co., Inc. (B)
Lehigh, Inc. (C)
Leitelt Bros., Inc. (A, B)
Lewistown Foundry & Machine Co. (C)
Light Metals, Inc. (A, D)
Lincoln Foundry Corp. (C)
Lincoln Iron Works (A, C)
Littite Foundries, Inc. (C)
Littlestown Hardware & Foundry Co., Inc. (A, B, C)
Lloyd & Scott Brass Foundry Inc. (A, B)
Lodge Mfg. Co. (C)
Loeffler, J. M. Co., Machine & Brass Works (B)
Lorain Brass Co. (B)
Lumen Bearing Co. (A, B, D, E, G, H)
Macaulay, H. C. Foundry Co. (C)
Mackintosh-Hemphill Div., E. W. Bliss Co. (F)
Madison Foundry Co. (C)
Magline, Inc. (D)
Mallory, P. R. & Co., Inc. (B)
Mansfield Brass & Aluminum Corp. (A, B)
Marshall Car Wheel & Foundry Co., Inc. (C)
McLanahan & Stone Corp. (A, C)
McNally Pittsburg Mfg. Co. (C)
Meehanite Metal Corp. (C)
Merrimac Brass (A, B)
Metal Goods Corp. (C, E, F)
Midwestern Foundries, Inc. (C)
Milwaukee Aluminum & Brass Foundry (A, B)
Milwaukee Valve Co. (A, B)
Minneapolis Electric Steel Casting Co. (F)
Mitchell, Robert Co., Ltd. (D)
Model Brass Co., Inc. (A, B)
Modern Brass Foundry & Mfg. Co. (A, B)
Montague Machine Co. (B, C, E)
Morse, Fred W. Co. (A, H)
Mueller Brass Co. (A, B)
Muskegon Piston Ring Co. (B, C)
National Aluminum & Brass Foundry, Inc. (A, B)
National Aluminum Co., Inc. (A, B)
National Brass Works, Inc. (A, B, E)
National Steel & Shipbuilding Corp. (C)
National Supply Co. (C, F)
Newman Bros. Inc. (A, B, E)
North Wales Foundry Co., Inc. (C)
Northern Malleable Iron Co. (C)
Oakes Bronze & Aluminum Co. (A, B)
Oakland Foundry & Machine Co. (C)
Ohio Malleable Div., Dayton Malleable Iron Co. (C)
Ohio Precision Castings, Inc. (A, B, E, H)
Ohio Steel Foundry Co. (E, F)
Oil City Iron Works (C)
Oklahoma Steel Castings Co. (F)
Olderman Mfg. Corp. (A, B)
Olds Alloys Co. (A, B, H)
Olympic Steel Works (F)
Omaha Steel Works (F)

Oregon Brass Works (A, B)
Owen Pattern Foundry & Mfg. Co., Inc. (A, B)

Pacific Brass Foundry of San Francisco (A, B, E, H)
Pacific Foundry Co. Ltd. (C, F)
Palmyra Foundry Co., Inc. (C)
Parker, Charles Co. (A, B)
Paulson, Thomas & Son, Inc. (A, B, E, H)
Pennsylvania Malleable Iron Corp. (C)
Pequonnock Foundry, Inc. (C)
Perkins, Henry Co. (C)
Permold Co. (A)
Pettibone Mulliken Corp. (F)
Pittsburgh Foundry & Machine Co. (C)
Pittsburgh Steel Foundry Corp. (F)
Pohlman Foundry Co., Inc. (C)
Portland Iron Works (C)
Potts, C. & G. & Co. (C)
Pratt, William E. Mfg. Co. (B)
Prescott Co. (C)

Quest, J. F. Foundry Co. (C)
Quality Castings Co. (D)

Refinery Castings Co. (C)
Reliance Steel Casting Co. (F)
Riverside Foundry Co. (A, C)
Riverside Foundry & Galvanizing Co. (A, B, C)
Rolle Mfg. Co. (A, D)
Rosedale Foundry & Machine Co. (C)
Ross-Meehan Foundries (C, F)

St. Louis Steel Casting Inc. (F)
St. Marys Foundry Co. (C)
Sall Bros. Co. (A, B)
Sandy Hill Iron & Brass Works (A, C)
Sargent & Greenleaf, Inc. (A)
Schilling Bronze Co. (A)
Schmeller Aluminum Foundry Co. (A)
Schneider Bowman Co., Inc. (C)
Scottdale Ozone Co. (A, C)
Scovill Mfg. Co. (B)
Scullin Steel Co. (F)
Searjeant Metal Products Inc. (A, C)
Selma Foundry & Machine Co. (C)
Sharpsville Steel Fabricators, Inc. (C, F)
Sheffield Foundry Co. (C)
Shenango Furnace Co. (C)
Sherman & Reilly, Inc. (A, C, F)
Shriver, T. & Co., Inc. (A, B, C)
Sibley Machine & Foundry Corp. (C)

Sinclair Co. (A, B)
Sioux City Foundry & Boiler Co. (A, C)
Sivyer Steel Casting Co. (F)
Smith & Winchester Mfg. Co. (A, B, C, F)
Somerset Foundry & Machine Co. (C)
Sonith Industries, Inc. (C)
Spencer's, I. S. Sons, Inc. (A, B, C)
Spring City Foundry Co. (C)
Springer's Foundry Co., Inc. (C)
Springfield Foundry Co. (C)
Spuck Iron & Foundry Co. (C)
Stainless Foundry & Engineering, Inc. (E)
Standard Casting Corp. (A, B)
Standard Foundry Co. (C)
Standard Steel Works, Div. of Baldwin-Lima-Hamilton Corp. (F)
Stanwood Corp. (F)
Stearns Roger Mfg. Co. (C)
Sterling Brass Foundry Inc. (A, B)
Sterling Foundry Co. (A)
Stillman White Foundry Co., Inc. (A, B)
Strong Steel Foundry Co. (F)
Stuart Foundry Co. (C)
Stulz-Sickles Co. (F)
Swedish Crucible Steel Co. (F)
Swett, A. L. Iron Works (C)

Taylor & Co. Inc. (C)
Taylor & Boggis Foundry (C)
Terre Haute Bronze & Brass Foundry (B)
Terre Haute Malleable & Mfg. Corp. (C)
Texas Foundries, Inc. (C, F)
Tower Grove Foundry (C)
Trenton Brass Co. (B)
True Alloys, Inc. (A, B, H)
Turner & Seymour Mfg. Co. (C)
Union Iron Works (C, F)
Unitcast Corp. (F)
U.S. Pipe and Foundry Co. (C)
Utica General Jobbing Foundry, Inc. (C)
Utica Radiator Corp. (C)
Valley Iron Works, Inc. (C)
Vulcan Foundry Co. (C)
Vulcan Rail & Construction Co. (A, C, F)
Wall Colmonoy Corp. (E)

Waltham Foundry Co. (A, C)
Washington Iron Works (C)
Waterman Industries, Inc. (A, B, C)
Waukesha Foundry Co. (A, B, E, F)
Wayne Agricultural Works, Inc. (B, C)
Wayne Foundry & Stamping Co. (H)
Weber-Knapp Co. (A)
Wellman Bronze and Aluminum Co. (A, D)
Werner Foundry & Machine Co. (C)
West Haven Foundry Co. (A, B)
Western Automatic Machine Screw Co. (C)
Western Foundry & Machine Works, Inc. (C)
Western Iron & Foundry Co., Inc. (C)
Westmoreland Malleable Iron Co. (C)
Williams, A. C. Co. (D)
Williams, E. A. & Son (A, B)
Winters Foundry & Machine Co., Inc. (A, B, E, H)
Wisconsin Aluminum Foundry Co., Inc. (A, B)
Wollaston Foundry Corp. (C)
Woodruff & Edwards, Inc. (C)
Zenith Foundry Co.

CASTINGS, SHELL MOLD

ABCO Aluminum & Brass Works (A, B, E)
Aelco Brass Foundry (A, B, E, F)
Albion Malleable Iron Co. (C)
Alloy Precision Castings Co. (C, F)
Almont Mfg. Co. (C)
American Brake Shoe Co.
American Cast Iron Pipe Co. (C, F)
American Manganese Steel Div., American Brake Shoe Co. (F)
American Steel Foundries (F)
Ampco Metal, Inc. (B)
Aurora Metal Co. (B)
Auto Specialties Mfg. Co. (F)
Bendix Aviation Corp. (A, D)
Bethlehem Steel Co. (F)
Cadillac Malleable Iron Co. (C)
Chicago Hardware Foundry Co. (A, B, C)
Chicago Malleable Castings Co. (C)
Cochrane Foundry, Inc. (A, B, H)
Cooper Alloy Corp. (F)
Crucible Steel Casting Co. (F)
Crucible Steel Co. of America (F)
Curtiss-Wright Corp. (F)

Dirilyte Co. of America, Inc. (B)
Electric Steel Foundry Co. (C, F)
Fischer Casting Co., Inc. (A)

Gale Mfg. Co. (C)
General Electric Co., Foundry Dept. (F)
General Motors Corp., Central Foundry Div. (C)
Gilbert Brass Foundry Co. (A, B)
Grimm Foundry Co., Inc. (C)
Gunite Foundries Corp. (C, F)

Hobbs, Clinton E. Co. (A, B, C)
Howard Foundry Co. (A, B, C, D, E, F)

Investment Casting Co. (A, B, E, F)

Jamestown Malleable Iron Corp. (C)

Laconia Malleable Iron Co. (C)
Lakeside Bronze Inc. (A, B)
Lebanon Steel Foundry (F)
Lehigh, Inc. (C)
Loeffler, J. M. Co. Machine & Brass Works (B)

Mallory, P. R. & Co., Inc. (B)
Marshall Car Wheel & Foundry Co., Inc. (C)
McCarter Iron Works Inc. (C, F)
Meehanite Metal Corp. (C)
Metal Goods Corp. (C, E)
Michigan Steel Casting Co., Div. of Consolidated Foundries & Mfg. Corp. (F)
National Bearing Div., American Brake Shoe Co. (A, B)
Northern Malleable Iron Co. (C)
Ohio Steel Foundry Co. (E, F)
Oklahoma Steel Castings Co. (F)
Olympic Steel Works (F)
Oregon Brass Works (A, B)
Parker, Charles Co. (A, B)
Pettibone Mulliken Corp. (F)
Pratt & Letchworth Div., Dayton Malleable Iron Co., Inc. (F)
Rolle Mfg. Corp. (A, D)
Ross-Meehan Foundries (C, F)
Sall Bros. Co. (A, B)
Schilling Bronze Co. (A)
Taylor & Co., Inc. (C)
Texas Foundries, Inc. (C, F)
Texas Steel Co. (F)
Trenton Brass Co. (B)
True Alloys, Inc. (A, B, H)
Unitcast Corp. (F)
Washington Iron Works (C)
Waukesha Foundry Co. (A, B, E, F)
Wayne Agricultural Works, Inc. (B, C)
Western Automatic Machine Screw Co. (C)
Winter Foundry & Machine Co., Inc. (A, B, E, H)
Woodruff & Edwards, Inc. (C)

CELLOPHANE (see Cellulose, Regenerated)

CELLULOSE ACETATE

Ace Plastic Co. (12, 13, 14)
Adhesive Products Corp. (18)
Albany Novelty Mfg. Co. (20)
American Hard Rubber Co. (12)
American Kleer-Vu Plastics, Inc. (20, 13)
American Molding Powder & Chemical Co. (22)
American Products Mfg. Co., Inc. (17, 20)
Anchor Plastics Co., Inc. (12, 14)
Auburn Plastic Engineering (13)
Bamberger, Claude P. Inc. (22)
Cadillac Plastic & Chemical Co. (20, 13, 14)
Carroll, J. B. Co. (13)
Celanese Corp. of America (17, 20, 22, 13)
Chicago Molded Products Corp., Campco Div. (20, 13)
Coating Products (20)
Commercial Plastics & Supply Corp. (12, 13, 14)
Craftint Mfg. Co. (13)
du Pont de Nemours, E. I. & Co., Inc. (19, 13)
Eastman Chemical Products, Inc. (17, 19, 22)
Eastman Kodak Co. (20, 13)
Falge Engineering Corp. (20)
Fry Plastics Co. (12, 13)
Gering Products, Inc. (22, 12, 14)
Glass Laboratories (12, 14)
Hercules Powder Co. (17, 22)
Industrial Plastics Corp. (12, 14)
Knoedler Chemical Co. (12, 13)
Luminous Resins, Inc. (22)
Monsanto Chemical Co. (20, 12, 13)
Muehlstein, H. & Co., Inc. (22)
Omni Products Corp. (22, 12, 13)
New England Tape Co. (12, 13)
Nixon Nitration Works (12, 13)
Pacific Coast Foil Co. (20)
Perfex Plastics, Inc. (12, 14)
Pyramid Plastics, Inc. (12, 14)
Reed Plastics Corp. (22)
Rosco Laboratories (20, 13)
Rowland Products, Inc. (12, 13, 14)
Schwab Plastics Corp. (21, 12, 14)
Simon Products Co. (20, 13)
Snyder Mfg. Co., Inc. (20, 13)
Southern Plastics Co. (20, 12, 13, 14)

Walsen Consolidated Mercantile Co. (12, 13)
Westlake Plastics Co. (12, 13)
World Plastex (12, 13, 14)

CELLULOSE ACETATE BUTYRATE

Adhesive Products Corp. (18)
American Hard Rubber Co. (12)
American Molding Powder & Chemical Co. (22)
Anchor Plastics Co., Inc. (12, 14)
Auburn Plastic Engineering (13)
Bamberger, Claude P. Inc. (22)
Cadillac Plastic & Chemical Co. (20, 12, 13, 14)
Carroll, J. B. Co. (13)
Chicago Molded Products Corp., Campco Div. (20, 13)
Coating Products (20)
Commercial Plastics & Supply Corp. (12, 13, 14)
Eastman Chemical Products, Inc. (17, 22)
Eastman Kodak Co. (20, 13)
Falge Engineering Corp. (20)
Gering Products, Inc. (22, 12, 14)
Glass Laboratories (12, 14)
Hydrawlik Co. (12, 14)
Industrial Plastics Corp. (12, 14)
KSH Plastics, Inc. (12, 13, 14)
Luminous Resins, Inc. (22)
Muehlstein, H. & Co., Inc. (22)
New England Tape Co., Inc. (12, 13)
Nixon Nitration Works (12, 13)
Omni Products Corp. (22, 12, 13)
Perfex Plastics, Inc. (12, 14)
Pyramid Plastics, Inc. (12, 14)
Rowland Products, Inc. (12, 13, 14)
Schwab Plastics Corp. (12, 14)
Shoe Form Co. (13, 14)
Snyder Mfg. Co., Inc. (20, 13)
Southern Plastics Co. (20, 12, 13, 14)
World Plastex (12, 13, 14)

CELLULOSE NITRATE

du Pont de Nemours, E. I. & Co., Inc. (13)
Falge Engineering Corp. (20)
Hercules Powder Co. (17, 12)
Monsanto Chemical Co. (20, 12, 13)
Nixon Nitration Works (12, 13)
Omni Products Corp. (12, 13)
Rowland Products, Inc. (13)

CELLULOSE PROPIONATE

Celanese Corp. of America (17, 22)
Perfex Plastics, Inc. (12, 14)
Southern Plastics Co. (20, 12, 13, 14)
World Plastex (12, 13, 14)

CELLULOSE, REGENERATED

(e.g., Cellophane)

Adhesive Products Corp. (18)
Aladdin Products Co. (13)
American Viscose Corp. (20)
Cadillac Plastic & Chemical Co. (20)
du Pont de Nemours, E. I. & Co., Inc. (19)
Mason Envelope Co., Inc. (20)
Pacific Coast Foil Co. (20)

CEMENTED CARBIDES

(see Ceramics)

CENTRIFUGAL CASTINGS

(see Castings)

CERAMIC COATINGS (see Coatings)

CERAMICS

(materials or parts incl refractories and cermets; no key indicates custom parts only; see also Mica)

Adamas Carbide Corp.
Aerovox Corp., Crowley Div. (9, 12, 23)
Alloy Metal Powders, Inc.
Allegheny Ludlum Steel Corp.
American Electro Metal Div., Firth-Sterling, Inc.
American Lava Corp. (9, 12, 23)
American Valve & Enameling Corp.
Amersil Co., Inc.
B. G. Corp.
Bay Ridge Specialty Co., Inc.
Beryl Ores Co.
Brush BeryHium Co. (9, 10, 12, 23)
Cedar Heights Clay Co. (10)
Centralab Div., Globe Union Inc. (12, 23)
Climax Molybdenum Co.
Coors Porcelain Co.
Corning Glass Works
Dixon, Joseph Crucible Co.
Dodge Fibers Corp. (12)
Du-Co Ceramics Co. (9, 10, 12, 23)
Edgar Plastic Kaolin Co.
Electrical Refractories Co. (23)
Electrometallurgical Co., Div. of Union Carbide Corp. (10)
Ferro Corp. (10)
Frenchtown Porcelain Co.
General Ceramics Corp. (12, 13, 23)
General Electric Co., Metallurgical Products Dept.
Georgia Kaolin Co.
Glass Laboratories
Heavy Minerals Co.
Hommel, O. Co. (10)
Illinois Minerals Co. (10)
Industrial Tectonics, Inc.
Ingram-Richardson, Inc.
Kennametal, Inc. (4, 5, 10, 12)
Knight, Maurice A.
Knox Porcelain Corp.
McDanel Refractory Porcelain Co. (9, 12, 23)
Metal & Thermit Corp.
Morganite Inc.
Mycalex Corp. of America (12)
Norton Co.
Porcelain Enamel Finishers (12, 23)
Porcelain Products, Inc. (23)
Porter, H. K. Co., Inc.
Quigley Co., Inc.
Sauereisen Cements Co. (10)
Saxonburg Ceramics (9, 10, 12, 23)
Seaboard Refractories Co.
Spruce Pine Mica Co., Inc. (9, 13)
Square D Co., Molded Insulation Div.
Stackpole Carbon Co.
Star Porcelain Co.
Steward, D. M. Mfg. Co. (12, 13, 23)
Stupakoff Div., Carborundum Co. (10, 12, 19)
Superior Steatite & Ceramic Corp. (12, 23)
Thermal Refractories Corp. (9, 12, 23)
Thermo Materials, Inc. (9, 12, 23, 13)
U.S. Stoneware Co. (12, 23)
Walsh Refractories Corp.

CERMETS (see Ceramics)

CHLOROSULFONATED POLYETHYLENE RUBBER

du Pont de Nemours, E. I. & Co., Inc.

CHLOROPRENE RUBBER

(Neoprene)

Adhesive Products Corp. (18)
American Hard Rubber Co. (12, 13, 14)
American Rubber Products Corp. (21, 13, 12, 14)
Atlas Mineral Products Co. (13)
Auburn Rubber Co., Inc. (13)
Brown Rubber Co., Inc. (21)
Chicago Rubber Co., Inc. (21, 22)
Continental Rubber Works (22, 12, 13, 14)
Coyne & Paddock, Inc. (13)
du Pont de Nemours, E. I. & Co., Inc. (17)
Foamade Industries (21)
Geauga Industries Co. (22, 12, 14)
Goshen Rubber Co. (22)
Home Rubber Co. (22, 12, 13, 14)
Johns-Manville Corp. (13)
Mid-States Rubber Products, Inc. (22, 13, 14)
Parker, Stearns & Co., Inc. (13, 14)
Raybestos-Manhattan, Inc. (12, 13, 14)
Rogers Corp. (12, 13, 14, 21, 22)
Roth Rubber Co. (22, 13)
Rubatex Div., Great American Industries, Inc. (21)
Standard Products Co. (22)
Stockwell Rubber Co., Inc. (21, 22, 12, 13, 14)
Technical Specialties Co. (14)
U.S. Stoneware Co. (22)
Vulcanized Rubber & Plastics Co. (22)

CHLOROTRIFLUOROETHYLENE

(see Fluorocarbon)

CHROMIUM

Alloy Metal Powder, Inc. (10)
American Nickel Alloy Mfg. Corp. (10)
Belmont Smelting & Refining Works, Inc. (8, 10)
Electro Metallurgical Co., Div. of Union Carbide Corp. (10)
Foote Mineral Co. (10)

KEY

MATERIALS

A—Aluminum and its alloys
B—Copper and its alloys
C—Iron and its alloys (except steel)
D—Magnesium and its alloys
E—Nickel and its alloys
F—Steels
G—Titanium and its alloys
H—Zinc and its alloys
J—Thermoplastics
K—Thermosetting plastics
L—Elastomers

BASIC FORMS

1—Anodes
2—Bar
3—Billets
7—Foil
8—Ingot
9—Plate
10—Powder
12—Rod
13—Sheet
14—Strip
17—Base resins, polymers or gums
18—Laminating or casting resins
19—Fibers or filaments
20—Film
21—Foams (component materials or products)
22—Molding compounds
23—Tube, nonmetallic (except plastics or rubber)

Hardy, Charles, Inc. (10)
Metal Hydrides Inc. (10)
Metals Disintegrating Co., Inc. (10)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (7, 8)
Sel-Rex Corp. (1)
Shieldalloy Corp. (10)

CLAD METALS

(key letters refer to base metal; see also Laminates, Metal-Metal)

Allegheny Ludlum Steel Corp. (F)
Aluminum Co of America (A)
American Silver Co., Inc. (B, C, E, F)
Bart Mfg. Corp. (F)
Bartlett-Thompson Co., Inc. (A, B, F)
Borg-Warner Corp. (F)
Darby Corp. (A, E, F)
Electric Steel Foundry Co. (E, F)
Electronic Parts Mfg. Co., Inc. (B)
Enamel Products Co. (A, F)
Fromson Orban Co., Inc. (C)
General Alloys Co. (E, F)
General Findings & Supply Co., Industrial Div. (B)
General Plate Div., Metals & Controls Corp. (A, B, C, D, E, F, G, H)
Improved Seamless Wire Co. (B, C, E)
Kaiser Aluminum & Chemical Sales, Inc. (A)
Kewaunee Engineering Corp. (C)
Leach & Garner Co., Industrial Div. (B, E)
Legion Utensils Co. (B, E, F)
Lukens Steel Co. (B, E, F)
McCarter Iron Works Inc. (F)
Metal Goods Corp. (B, E, F)
Parish Pressed Steel Div., Dana Corp. (A, F, H)
Presswork Inc. (B)
Republic Steel Corp. (F)
Revere Copper and Brass, Inc. (A, B)
Reynolds Metals Co. (A)
Ryerson, Joseph T. & Son, Inc. (F)
Seattle Boiler Works, Inc. (F)
Sharpsville Steel Fabricators, Inc. (F)
Somers Brass Co., Inc. (E)
Superior Steel Corp. (B, E, F)
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp. (F)

COATINGS (see below; also Anodizers, Electroplaters, Precoated Metals, Prepainted Metals, Preplated Metals)

COATINGS, CHEMICAL CONVERSION (formulations)

Allied Research Products, Inc.
American Chemical Paint Co.
American Cyanamid Co.
Borden Co., Chemical Div.
Chemical Corp.
Colonial Alloys Co.
Conversion Chemical Corp.
Detrex Chemical Industries Inc.
Diversey Corp.
Enthone, Inc.
General Plastics Corp.
Gumm, Frederick Chemical Co., Inc.
Heat Bath Corp.
Hull, R. O. & Co., Inc.
Kelite Corp.
Metal & Thermit Corp.
Mitchell-Bradford Chemical Co.
Neilson Chemical Co.
Northwest Chemical Co.
Oakite Products, Inc.
Panther Chemical Corp.
Parker Rust Proof Co.
Pennsalt Chemicals Corp.
Turco Products, Inc.

COATINGS, METALLIZED— METALLIZING WIRE

Alloy Metal Wire Co., Inc.
Alphaloy Corp., Div. of Alpha Metals Inc.
Armco Steel Corp.
Colonial Alloys Co
Metallizing Engineering Co., Inc.
Vandersee Corp.
White Metal Rolling & Stamping Corp.

COATINGS METALLIZED— SPRAY METALLIZERS

Continental Boiler & Sheet Iron Works
Hayden Wire Works, Inc.
Jema Chemical & Supply Co.
Metal-Cladding, Inc.
Metallizing Co. of America
Metallizing Engineering Co., Inc.
Metalweld Inc.
Schori Process Div., Ferro-co Corp.
Superior Plating Inc.
Tickle, Arthur Engineering Works, Inc.
Wall Colmonoy Corp.

COATINGS, METALLIZED— VACUUM METALLIZERS

Adams Plastic Products
Closures Inc.
Coating Products
Consolidated Electrodynamics Corp.
Davis Products Corp.
Eyelet Specialty Co.
Hastings & Co., Inc.
International Optical Co.
Jema Chemical & Supply Co.
Metallizing Co. of America
Metaplast Process, Inc.
Shelby Instrument Co.
Sylvania Electric Products, Inc.

COATINGS, ORGANIC (enamels, lacquers, etc.)

Acorn Refining Co.
Adelphi Paint & Color Works, Inc.
Albi Mfg. Co., Inc.
Allied Chemical & Dye Corp.
Allsuede Products, Inc.
Alpha Molykote Corp.
Aluminum Finishing Corp.
Amercoat Corp.
American Cyanamid Co.
American Luminous Products Co.
American Products Mfg. Co., Inc.
American Sand-Banum Co., Inc.
American Solder & Flux Co.
Arbonite Corp.
Arco Co.
Armitage, John L. & Co.
Ashtabula Mfg. Co.
Atech, Inc.
Avondale Co.
Barrett Varnish Co.
Bishopric Products Co.
Bisonite Co., Inc.
Black Bear Co., Inc.
Blaco Mfg. Co.
Boatwright Paint & Varnish Works, Inc.
Borden Co., Chemical Div.
Both, O. A. Corp.
Bradley & Vrooman Co.
Bradley Paint Co.
Brewer-Titchener Corp.
Brooklyn Paint & Varnish Co., Inc.
Calbar Paint & Varnish Co.
Campbell, A. S. Co., Inc.
Capitol Chemical Co.
Carboline Co.
Ceilcote, Co., Inc.
Central Paint & Varnish Works, Inc.
Chemical Products Corp.
Chicago Paints, Inc.
Chicago Thrift-Etching Corp.
Columbus Dental Mfg. Co.
Continental Products Co.
Davis, H. B. Co.
Day, James B. & Co.
Debevoise Co.
Dennis Chemical Co.
DeSoto Paint & Varnish Co.
Dip Seal Plastics, Inc.
du Pont de Nemours, E. I. & Co., Inc.
Duralac Chemical Corp.
Earl Paint Corp.
Eastern States Paint & Varnish Co.
Egan and Hausman Co., Inc.
Egyptian Lacquer Mfg. Co.
Emjay Maintenance Engineers
Felton, Sibley & Co., Inc.
Fidelity Chemical Products Corp.
Firestone Plastics Co.
Flood Co.
Forbes Finishes Div., Pittsburgh Plate Glass Co.
Forman, Ford & Co.
Foundry Rubber, Inc.
Gates Engineering Co.
General Electric Co.
General Paint Corp.
General Plastics Corp.
Georgia Kaolin Co.
Gillespie Varnish Co.
Glidden Co.
Globe Paint Works, Inc.
Grand Rapids Varnish Corp.
Grems Mfg. Co.
Gusmer, A. Inc.
Hanline Bros.
Harrison Paint & Varnish Co.
Hilo Varnish Corp.
Hofford Varnish Co., Inc.
Horn, A. C. Co., Inc.
Houghton Laboratories, Inc.
Houze Glass Corp.
Industrial Metal Protectives, Inc.
Interchemical Corp.
Jamestown Finishes, Inc.
Jamestown Paint & Varnish Co.
Jasper Lacquer Co., Inc.
Kano Laboratories
Kepec Chemical Corp.
Keystone Refining Co., Inc.
Knight, Maurice A.
Lacquer & Chemical Corp.
Lacquer Products, Inc.
Landau, J. & Co., Inc.
Lithcote Corp.
Lockrey-Fater Corp.
Logo, Inc.
Longview Paint & Varnish Co.
Lowe Bros. Co.
Maas & Waldstein Co.
Magic Chemical Co.
Martin Varnish Co.
Master Bronze Powder Co., Inc.
McDougall Butler Co., Inc.
Mearl Corp.
Merix Chemical Co.
Merkin, M. J. Paint Co., Inc.
Metal & Thermit Corp.
Michigan Chrome & Chemical Co.
Midland Adhesive & Chemical Corp.
Midland Industrial Finishes Co.
Midland Paint & Varnish Co.
Minnesota Mining & Mfg. Co., Adhesives & Coatings Div.
Minnesota Platon Corp.
Missouri Paint & Varnish Co.
Mobile Paint Mfg. Co., Inc.
Modern Plating Corp.
Monroe Co., Inc.
Monroe, Lederer & Taussig, Inc.
National Mfg. Corp.
National Paint Products, Inc.
National Polymer Products, Inc.
Naugatuck Chemical Div., U.S. Rubber Co.
Nikolas, G. J. & Co., Inc.
Nukem Products Corp.

Paisley Products, Inc., Div. of Morningstar, Nicol, Inc.
Paramount Paint & Lacquer Co.
Parker Paint Mfg. Corp.
Parr Paint & Color Co.
Patterson-Sargent Co.
Payson Corp.
Perry-Austen Mfg. Co.
Pierce & Stevens Chemical Corp.
Pierce, F. O. Co.
Polymer Chemical Co.
Pratt & Lambert, Inc.
Prisma Products Corp.
Quigley Co., Inc.
Randolph Products Co.
Raybestos-Manhattan, Inc.
Reliance Varnish Co.
Reynolds Chemical Products, Inc.
Riegel Paper Corp.
Rinshed-Mason Co.
Rust-Oleum Corp.
Sauereisen Cements Co.
Schori Process Div., Ferro-co Corp.
Sealube Co.
Seaporcel Metals, Inc.
Sheffield Bronze Paint Corp.
Sherwin-Williams Co.
Spraylat Corp.
Spring Packing Corp.
Stanley Chemical Co.
Steel Protection & Chemical Co., Inc.
Steelcote Mfg. Co.
Subox, Inc.
Superior Paint & Lacquer Works
Tect, Inc.
Thermal Refractories Corp.
Thompson & Co.
Tousey Varnish Co.
Union Chemical Corp.
Valvoline Oil Co., Div. of Ashland Oil & Refining Co.
Vanguard Paints and Finishes, Inc.
Vulcan Varnish Co.
Western Coating Co.
Westinghouse Electric Corp.
X-Pando Corp.
Zophar Mills, Inc.

COATINGS, ORGANIC—FINISHERS

Arbonite Corp.
Bishopric Products Co.
Caspers Tin Plate Co.
Coated Coil Corp.
Cohan Epner Co., Inc.
Colonial Alloys Co.
Cordo Chemical Corp.
Gates Engineering Co.
Magic Chemical Co.
Metalweld Inc., Protective Coating Div.
Met-L-Wood Corp.
Michigan Chrome & Chemical Co.
Polacoat Inc.
Schori Process Div., Ferro-co Corp.

COATINGS, STRIPPABLE

Adhesive Products Corp.
American Latex Products Corp.
Atlas Mineral Products Co.
Babbitt Chemical Co.
Bakelite Co., Div. of Union Carbide Corp.
Belding-Corticelli Industries
Better Finishes & Coatings Inc.
Bischoff Chemical Corp.
Bisonite Co.
Borden Co.
Carboline Co.
Carey Philip Mfg. Co.
Chemical Products Corp.
Commercial Chemical Co.
Daubert Chemical Co.
Dennis Chemical Co.
Dow Chemical Co.
Fine Organics Inc.
Frost Paint & Oil Corp.
George, P. D. Co.
Glidden Co.
Globe Imperial Corp., Plastic-Seal Div.
Houghton, E. F. Co.
Jones Dabney Co.
Koster-Keunen Mfg. Co., Inc.
Metal & Thermit Corp.
Michelman Chemicals, Inc.
Midland Adhesive & Chemical Corp.
Minnesota Mining & Mfg. Co.
Munray Products Inc., Div. of Fanner Mfg. Co.
Nikolas, G. J. & Co., Inc.
Octagon Process, Inc.
Paisley Products Inc.
Pierce & Stevens Chemical Corp.
Polyken Sales Div., Kendall Co.
Polymer Chemical Co.
Presstite-Keystone Engineering Products Co.
Protective Treatments Inc.
Puritan Co., Inc.
Pyramid Plastics Inc.
Spraylat Corp.
Texas Plastic Development Corp.
Thompson & Co.
U.S. Rubber Co.
Valvoline Oil Co., Div. of Ashland Oil & Refining Co.
Watson Standard Co., Industrial Safety Products Div.
Xylos Rubber Co.
Zophar Mills Inc.

COATINGS, VITREOUS—ENAMELERS

Allianceware, Inc.
American Valve & Enameling Corp.
Atlas Enameling Co., Inc.
Bally Metal Products, Inc.
Barrows Porcelain Enamel Corp.
Benjamin Electric Mfg. Co.
Bettinger Corp.
Bulwark Corp. of America
California Metal Enameling Co.
Caloric Appliance Corp.
Century Vitreous Enamel Co.
Challenge Stamping & Porcelain Co.
Cleveland Porcelain Enameling Co.
Crane Steelware Ltd.
Edna Lite Optical Co., Inc.
Emco Porcelain Enamel Co.
Enamel Products Co.
Erie Ceramic Arts Co.
Erie Enameling Co.
Ervite Corp.
Ferro Enameling Co.
Fletcher Enamel Co.
Frenchtown Porcelain Co.
Geuder, Paeschke & Frey Co.
Hayden Wire Works Inc.
Heintz Mfg. Co.
Houston Porcelain Enameling Co.
Independence Stove & Mfg. Co.
Ingersoll Products Div., Borg-Warner Co.
Ingram-Richardson, Inc.
Ingram-Richardson Mfg. Co.
Jeannette Shade & Novelty Co.
Jones Metal Products Co.
Kaiser Metal Products, Inc.
Lancaster Glass Corp.
Lansdale Porcelain Enamel Corp.
Pittsburgh Plate Glass Co.
Porcelain Enamel Finishers
Pyrosil, Inc.
Rheem Mfg. Co.
Rutenber Electric Co.
Seaholtz, J. M. & Sons, Inc.
Seaporcel Metals, Inc.
Smith, A. O. Corp.
Smoot-Holman Co.
Southwestern Porcelain Steel Corp.
Temco, Inc.
Tennessee Stove Works
Texlite, Inc.
U.S. Plywood Corp.
U.S. Porcelain Enamel Co.
U.S. Stoneware Co., Alite Div.
Vitreous Steel Products Co.
Wolverine Porcelain Enameling Co.

COATINGS, VITREOUS—FRITS AND FORMULATIONS

Beryl Ores Co.
Ceramic Color and Chemical Mfg. Co.
Chicago Vitreous Corp.
du Pont de Nemours, E. I. & Co., Inc.
Ferro Corp.
Georgia Kaolin Co.
Harshaw Chemical Co.
Hommel, O. Co.
Ingram-Richardson, Inc.
Metallizing Engineering Co., Inc.
Norton Co.
Pemco Corp.
Pyrosil, Inc.
Thermal Refractories Corp.

COATINGS AND SURFACES FOR METALS, HARD (see also Anodizers; Electroplaters; Hard Facing Alloys; Coatings, Vitreous; and Coatings, Metallized)

Calorizing Co.
Chromalloy Corp.
Electrolizing Corp.
Kanigen Div., General American Transportation Corp.
Linde Air Products, Div. of Union Carbide Corp.
Van der Horst Corp.

COBALT AND ITS ALLOYS

Alloy Metal Powders, Inc. (10)
American Nickel Alloy Mfg. Corp. (8)
Belmont Smelting & Refining Works, Inc. (10)
Crobalt, Inc. (1, 8, 12)
Driver, Wilbur B. Co. (12, 14)
Driver-Harris Co. (12, 14)
Elgin National Watch Co. (3, 12, 14)
General Plate Div., Metals & Controls Corp. (7, 14)
Hardy, Charles, Inc. (10)
Haynes Stellite Co., Div. of Union Carbide Corp. (2, 9, 12, 13, 14)
Hoskins Mfg. Co. (12, 14)
Metal Hydrides, Inc. (10)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc (7, 8)
Vacuum Metals Corp., Div. Crucible Steel Co. of America (2, 3, 8, 9, 13, 14)
Wall Colmonoy Corp. (10, 12)

COLD HEADED PARTS

Acme Machine Products Div., Serrick Corp. (B, F, H)
Allmetal Screw Products Co., Inc. (E, F, G)
Anti-Corrosive Metal Products Co., Inc. (F)
Armco Steel Corp., Sheffield Div. (F)
Art Wire & Stamping Co. (A, B, C, D, E, F, G, H)
Champion Rivet Co. (C, F)
Chase Brass & Copper Co. (B)
Chicago Rivet & Machine Co. (A, C, F)
Cincinnati Pump & Mfg. Co., Inc. (F)
Clark Bros. Bolt Co. (A, B, C, F)
Clendenin Bros. Inc. (A, B, C)
Columbus Bolt & Forging Co. (A, B, F)
Elco Tool and Screw Corp. (A, B, C, F)
Etched Products Corp. (A)
General Findings & Supply Co., Industrial Div. (B)
Gibson Electric Co. (E)
Greene, G. G. Corp. (F)

Grip Nut Co. (A, B, F)
Harper, H. M. Co. (A, B, E, F)
Hassall, John Inc. (A, B, C, E, F, H)
Hercules Fastener Co. (A, B, C, F, H)
Huck Mfg. Co. (A, F)
McKinney Mfg. Co. (A, B, C, D, E, F)
Milford Rivet & Machine Works (A, B, F)
Murray Tube Works, Inc. (A, B, F)
Mutual Screw & Supply Corp. (A, B, C, F)
Reed & Prince Mfg. Co. (A, B, C, F)
Republic Steel Corp. (F)
Russell, Burdsall & Ward Bolt and Nut Co. (A, B, F)
Scovill Mfg. Co. (A, B)
Shakeproof Div., Illinois Tool Works (A, B, F)
Torrington Co. (A, F)
Tubular Rivet and Stud Co. (A, B, C, E, F)
Union Screw & Mfg. Co. (A, F)
Western Automatic Machine Screw Co. (A, B, F)

COLUMBIUM AND ITS ALLOYS

Electro Metallurgical Co., Div. of Union Carbide Corp. (2, 8, 10, 12)
Fansteel Metallurgical Corp. (2, 8, 9, 10, 12, 13, 14)
Kennametal, Inc. (10)
Metal Hydrides, Inc. (10)
Shieldalloy Corp. (10)

COMPRESSION MOLDINGS

(see Moldings)

COPPER AND ITS ALLOYS

Ajax Metal Div., H. Kramer & Co. (8)
Alpha Metals, Inc. (7)
American Brass Co. (12, 13)
American Manganese Bronze Co. (2, 12)
American Metal Co., Ltd. (1, 2, 3, 8, 10)
American Nickel Alloy Mfg. Corp. (8)
American Silver Co. (7, 14)
American Smelting & Refining Co., Continuous Cast Products Dept. (2)
Ampco Metal, Inc. (2, 8, 9, 12, 13, 14)
Avril, G. A. Co. (8)
Barth Smelting Corp. (8)
Bay State Refining Co., Inc. (8)
Belmont Smelting & Refining Works, Inc. (1, 8, 10)
Beryllium Corp. (2, 3, 7, 8, 10, 12, 14)
Bohn Aluminum & Brass Corp. (2, 8, 12)
Both, O. A. Corp. (10)
Bridgeport Brass Co. (9, 12, 13, 14)
Bridgeport Rolling Mills Co. (13, 14)
Bristol Brass Corp. (1, 2, 3, 7, 9, 12)
Brush Beryllium Co. (2, 3, 8, 9, 14)
Bullock, W. J. Inc. (8)
Chase Brass & Copper Co., Inc. (1, 2, 9, 12, 13, 14)
Chicago Extruded Metals Co. (12)
Driver, Wilbur B. Co. (12, 14)
Driver-Harris Co. (12, 14)
Electric Materials Co. (1, 2, 12)
Federated Metals Div., American Smelting and Refining Co. (1, 2, 3, 8)
General Plate Div., Metals & Controls Corp. (7)
Glidden Co. (10)
Grand Rapids Brass Co. (9)
Greenback Industries, Inc. (10)
H & H Tube & Mfg. Co. (14)
Hardy, Charles Inc. (10)
Harris, Benjamin & Co. (8)
Hayden Wire Works, Inc. (12)
Hettleman, K. & Sons, Inc. (8)
Hommel, O. Co. (10)
Hoskins Mfg. Co. (12, 14)
Hussey, C. G. & Co., Div. of Copper Range Co. (1, 2, 7, 9, 12, 13, 14)
Inspiration Consolidated Copper Co. (1, 2, 3)
Instrument Specialties Co., Inc. (14)
Laminated Shim Co. (13)
Langsenkamp, F. H. Co. (2, 9, 12, 13, 14)
Lavin, R. & Sons, Inc. (1, 8)
Leach & Garner Co., Industrial Div. (14)
Lewin-Mathes Co. (12)
Loewenthal Metals Corp. (8)
Magna Mfg. Co., Inc. (10)
Mallory, P. R. & Co., Inc. (2, 9, 12, 13, 14)
Malone Bronze Powder Works, Inc. (10)
Malone Metal Powders, Inc. (10)
McGean Chemical Co. (1)
Metal & Thermit Corp. (1)
Metals Disintegrating Co., Inc. (10)
Miller Co. (13)
Mueller Brass Co. (12)
New England Brass Co. (1, 2, 12, 13, 14)
New England Smelting Works, Inc. (8)
New Haven Copper Co. (1, 9, 13, 14)
New Jersey Metals Co. (1)
New Jersey Zinc Co. (10)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (7, 8)
Olin Mathieson Chemical Corp. (13)
Peerless Roll Leaf Co., Inc. (7, 14)
Phelps Dodge Copper Products Corp. (14)
Phelps Dodge Refining Corp. (1, 2)
Plume & Atwood Mfg. Co. (13, 14)
Revere Copper and Brass, Inc. (1, 2, 7, 9, 12, 13, 14)
Rigidized Metals Corp. (13, 14)
Riverside Metal Alloy Div., H. K. Porter Co., Inc. (2, 12, 13, 14)
Schumann, I. & Co. (8)
Scovill Mfg. Co. (12, 13, 14)
Sel-Rex Corp. (1, 10)
Seymour Mfg. Co. (1, 12, 13, 14)
Sipi Metals Corp. (8)
Somers Brass Co., Inc. (14)
Sonken-Galamba Corp. (8)
Stamford Rolling Mills Co. (13)
Thinsheet Metals Co. (13)
Titan Metal Mfg. Co. (2, 12)
U.S. Bronze Powder Works, Inc. (10)
U.S. Metal Products Co. (8)
Universal Castings Corp. (8)
Utility Mfg. Co. (2, 12)
Vacuum Metals Corp., Div. Crucible Steel Co. of America (2, 3, 8, 9, 13, 14)
Volco Brass & Copper Co. (13)
Wall Colmonoy Corp. (10)
Waterbury Rolling Mills, Inc. (14)
Whitehead Metal Products Co., Inc. (9, 12, 13, 14)

CORDIERITE

(see Ceramics)

CORK

Armstrong Cork Co.
Hollingsworth & Vose Co.
Spring Packing Corp.
United Cork Companies

CORRUGATED METALS

Acorn Iron & Supply Co. (A, F)
Aetna Steel Co. (F)
Albert Pipe Supply Co., Inc. (F)
American Sheet Metal Works, Inc. (A, F)
Armco Steel Corp. (C, F)
Bethlehem Steel Co. (F)
Cartwright, R. Tube Products Co. (A)
Clendenin Bros. Inc. (A)
Conner Mfg. Co. (C)
Guilfoy Cornice Works (A, C)
Hussey, C. G. & Co., Div. of Copper Range Co. (B)
Illinois Zinc Co., Div. of Hydrometals, Inc. (H)
Inland Steel Co. (F)
Johnson Metal Hose, Inc. (B, E, F)
Kaiser Aluminum & Chemical Sales, Inc. (A)
Levinson Steel Co. (A, F)
Lincoln Steel Corp. (F)
Matthiessen & Hegeler Zinc Co. (H)
McNally Pittsburg Mfg. Co. (A, F)
Metal Goods Corp. (A)
Missouri Boiler & Sheet Iron Works (C, F)
New York Iron Roofing & Corrugating Co., Inc. (A, F)
Powell Pressed Steel Co. (A, F)
Republic Steel Corp. (C, F)
Reynolds Metals Co. (A)
Ryerson, Joseph T. & Son, Inc. (A, F)
U.S. Steel Corp. (F)
Ward, H. H. Co. (A, F)
Whitehead Metal Products Co., Inc. (A, B)

CUPRO-NICKEL

(see Copper)

DIALLYL PHTHALATE (DAP)

Durez Plastics Div., Hooker Electrochemical Corp. (22)
Formica Corp. (12, 13, 14)
Interchemical Corp. (17, 18, 22)
Mesa Plastics Co. (22)
Ohio Apex Div., Food Machinery & Chemical Corp. (17)
Reichhold Chemicals, Inc. (17, 18)
Synthane Corp. (13)

DIE CASTINGS

(see Castings)

DRAWN METAL PARTS

(see Formed Metal Shapes)

DROP FORGINGS

(see Forgings)

DUCTILE IRON

(see Iron)

ELECTROPLATERS

Acme Plating Co.
Allied Research Products, Inc.
American Emblem Co., Inc.
American Nickeloid Co.
Apollo Metal Works
Atlantic Brass Works, Inc.
Bethlehem Steel Co.
Brewer-Titchener Corp.
Campbell, A. S. Co., Inc.
City Plating Works, Inc.
Cohan Epner Co., Inc.
Colonial Alloys Co.
Columbus Dental Mfg. Co.
Dalic Metachemical Ltd.
Edna Lite Optical Co., Inc.
Industrial Chromium Corp.
K & L Plating Co.
Lakeland Industries
Master Chrome Service Inc.
Mechanical Plating Co.
Medico Industries, Inc.
Michigan Chrome & Chemical Co.
Modern Plating Corp.
Olean Electro Plating Co.
Republic Steel Corp.
Semon Bache & Co.
Steel Protection & Chemical Co., Inc.
Thermo Materials, Inc.
Van der Horst Corp.
Wayne Foundry & Stamping Co.

EMBOSSED METALS (Incl rigidized)

American Nickeloid Co. (A, B, F, H)
Auld, D. L. Co. (A, B)
Colonial Alloys Co. (A, B, D, E, F, G, H)
Cooley, W. J. & Co. (A, B, F)
Electric Steel Foundry Co. (F)
Fairmont Aluminum Co. (A)
Falstrom Co. (A, B, C, D, F)
Grammes, L. F. & Sons, Inc. (A, B, F)
Hawkridge Bros. Co. (A)
Langsenkamp, F. H. Co. (A)

Mahon, R. C. Co. (A)
McKinney Mfg. Co. (A, B, D, E, F)
Metal Goods Corp. (A, B, E, F)
Morse, Fred W. Co. (A, B, C, F)
Parker Metal Goods Co. (A, F)
Premier Metal Works, Inc. (A, B, E, F)
Republic Steel Corp. (F)
Reynolds Metals Co. (A)
Rigidized Metals Corp. (A, B, F, G)
Whitehead Metal Products Co., Inc. (A, B, E, F)
Wilson-Hurd Mfg. Co., Inc. (A)

EPOXIES

Adhesive Products Corp. (18)
Angier Adhesives, Div. of Interchemical Corp. (18)
Armstrong Products Co. (18)
Bakelite Co., Div. of Union Carbide Corp. (17, 18, 22)
Biggs, Carl H. Co., Inc. (12, 13)
Bisonite Co., Inc. (18)
Borden Co., Chemical Div. (17, 18)
Cadillac Plastic & Chemical Co. (18, 12, 13, 14)
Ciba Co. Inc., Plastics Div. (17, 18)
Commercial Plastics & Supply Corp. (12, 13, 14)
Dennis Chemical Co. (18)
Formica Corp. (12, 13, 14)
Foss Mfg. Co., Plastics Div. (18)
Furane Plastics Inc. (18, 22)
Glo-Brite Products, Inc. (21)
Hardman, H. V. Co., Inc. (18)
Jones-Dabney Co. (17, 18, 21)
Marblette Corp. (18, 21)
Minneapolis-Honeywell Regulator Co. (18, 21, 22)
Minnesota Mining & Mfg. Co. (18, 19, 22, 12, 13)
National Vulcanized Fibre Co. (13)
New England Laminates Co., Inc. (13)
Northern Plastics Corp. (13, 14)
Ohio Adhesives Corp. (18)
Philrus Products Co. (12, 13, 14)
Pyrosil, Inc. (18, 13)
Reichhold Chemicals, Inc. (17, 18)
Ren Plastics Inc. (17, 18)
Rezolin, Inc. (18)
Rogers Corp. (22)
Schwartz Chemical Co., Inc. (18)
Shell Chemical Corp. (17)
Strick Plastics Co. (21, 13)
Synthane Corp. (12, 13, 14)
Taylor Fibre Co. (13)

ETHYL CELLULOSE

Adhesive Products Corp. (18)
American Hard Rubber Co. (12)
American Molding Powder & Chemical Co. (22)
American Products Mfg. Co., Inc. (20)
Anchor Plastics Co., Inc. (12, 14)
Bamberger, Claude P. Inc. (22)
Carroll, J. B. Co. (13)
Chicago Molded Products Corp., Campco Div. (20, 13)
Dow Chemical Co. (22, 12, 13)
Faige Engineering Corp. (20)
Gering Products, Inc. (22, 12, 14)
Glass Laboratories (12, 14)
H & R Industries (12, 13, 14)
Hercules Powder Co. (17, 22)
Hydrawlik Co. (12, 14)
Industrial Plastics Corp. (12, 14)
KSH Plastics, Inc. (12, 13, 14)
Muehlstein, H. & Co., Inc. (22)
Nixon Nitration Works (12, 13)
Omni Products Corp. (22, 12, 13)
Perfex Plastics, Inc. (12, 14)
Pyramid Plastics, Inc. (14)
Schwab Plastics Corp. (12, 14)
Simon Products Co. (20)
Southern Plastics Co. (20, 12, 13, 14)
World Plastex (12, 13, 14)

EXPANDED METALS

American Sheet Metal Works, Inc. (A, F)
Colonial Alloys Co. (A, B, D, E, F, G, H)
Designers Metal Corp. (A, B, C, E, F)
Evans, George Corp. (A)
Flexonics Corp. (F)
Haven-Busch Co. (F)
Hawkridge Bros. Co. (A)
Hazledine, E. T. Co (F)
Houston Blow Pipe & Sheet Metal Works (F)
Levinson Steel Co. (A, F)
Metal Goods Corp. (A, B, E, F)
Republic Steel Corp. (F)
Ryerson, Joseph T. & Son, Inc. (A, F)
Trojan Steel Co. (F)
U.S. Gypsum Co. (A, F)
Vulcan Rail & Construction Co. (F)
Ward, H. H. Co. (F)
Whitehead Metal Products Co., Inc. (A, B, E, F)
Whyte, Oliver Co., Inc. (A, F)

EXTRUSIONS

(see below; also Impact Extrusions, Tubing)

EXTRUSIONS, METALLIC

(excl Tubing, Pipe)

Accurate Metal Weather Strip Co., Inc. (A, B)
Allegheny Ludlum Steel Corp. (F)
Aluminum Co. of America (A, D)
Aluminum Extrusions, Inc. (A)
American Brass Co.
American Machine & Foundry Co. (F, G)
American Reed Co., Inc. (D)
Ampco Metal, Inc. (B)
Auld, D. L. Co. (A)
B & T Metals Co. (A)
Babcock & Wilcox Co., Tubular Products Div. (C, F, G)
Beck, I. & Sons, Inc. (A, B)
Belmont Aluminum Extrusion Co. (A)
Benada Aluminum Products Co. (A)
Bohn Aluminum & Brass Corp. (A)
Bossert Div., Rockwell Spring and Axle Co. (F)
Bridgeport Brass Co. (A, G)
Brinkerhoff Brass & Bronze Works, Inc. (A, B)
Chase Brass & Copper Co. (B, G)
Clendenin Bros. Inc. (A, B)
Columbus Bolt & Forging Co. (A, B, F)
Craft Mfg. Co. (A, B, C, D, E, F, G, H)
Curtiss-Wright Corp. (F, G)
Cyril Bath Co. (A, G)
Detroit Casket & Mfg. Co., Extruded Metals Div. (A)
Dixie Aluminum Corp. (A)
Dixie Bronze Co. (B)
Dominion Magnesium, Ltd. (D)
Dow Chemical Co. (D)
Empire Aluminum Co. (A)
Etched Products Corp. (A)
Eureka Electrical Products Co. (B)
Flynn, Michael Mfg. Co. (A)
Frasse, Peter A. & Co., Inc. (A, F)
Fromson Orban Co., Inc. (A)
Fuller, W. P. & Co. (H)
General Extrusions, Inc.
Harvey Aluminum Div., Harvey Machine Co., Inc. (A, F, G)
Hawkridge Bros. Co. (A)
Himmel Bros. Co. (A)
Hokin Aluminum Co. (A)
Hunter Douglas Aluminum Corp. (A, B)
Jarl Extrusions Co. (A)
Jasco Aluminum Products Co. (A)
Jones & Laughlin Steel Corp. (F)
Kaiser Aluminum & Chemical Sales, Inc. (A)
Kawneer Co. (A)
Kidd Drawn Steel Co. (F)
Kroh Wagner (A)
Light Metals Corp. (A)
Metal Goods Corp. (A)
Metal Trims, Inc. (A)
Monarch Tool & Mfg. Co. (A)
National Aluminum Co. (A)
New Jersey Aluminum Extrusion Co., Inc. (A)
Olin Mathieson Chemical Corp. (A)
Parish Pressed Steel Div., Dana Corp. (F)
Penn Brass & Copper Co. (A)
Penn Extrusion Corp. (A)
Pfister Aluminum Corp. (A)
Phelps Dodge Copper Products Corp. (B)
Precision Extrusions, Inc. (A)
Republic Steel Corp. (F)
Revere Copper & Brass, Inc. (A, B)
Reynolds Metals Co. (A)
Scovill Mfg. Co. (B)
Southern Extrusions Co. (A)
Stainless Metals, Inc. (F)
Steel Industries, Inc. (B, F)
Superior Industries, Inc. (A)
Titan Metal Mfg. Co. (B)
Titanium Metals Corp. of America (G)
Toledo Stamping & Mfg. Co. (A, F)
Trim Alloys, Inc. (A)
U.S. Extrusions Corp. (A)
U.S. Steel Corp. (F)
Vulcan Metal Products, Inc. (A)
Vulcan Rail & Construction Co. (A)
W. F. Mfg. Co. (A)
Wells Aluminum Products Co. (A)
Werner, R. D. Co., Inc. (A)
White Metal Rolling & Stamping Corp. (D)
Whitehead Metal Products Co., Inc. (A, B, E)
Wolverine Tube Div., Calumet & Hecla, Inc. (A)
Woodlin Metal Products Co. (A)
Worcester Pressed Steel Co. (A, F)
Youngstown Kitchens Div., American Standard Co. (F)
Youngstown Mfg., Inc. (A)

EXTRUSIONS, NONMETALLIC

(excl Tubing, Pipe)

Ace Plastic Co. (J)
Allegheny Plastics, Inc. (J)
Amco Plastic Pipe Co. (J)
American Agile Corp. (J)
American Hard Rubber Co. (J, K, L)
American Molding Co. (J)
American Plastics Corp. (J)
Anchor Plastics Co., Inc. (J)
Anesite Co. (J)
Atlas Mineral Products Co. (J)
Bond International Inc. (L)
Bowling Green Rubber Co. (L)
Brown Rubber Co., Inc. (L)
Button Corp. of America (J)
Cadillac Plastic & Chemical Co. (J)
Chardon Rubber Co. (J)
Colonial Plastics Mfg. Co. (J)
Conneaut Rubber & Plastics Co. (J, L)
Connecticut Hard Rubber Co. (L)
Continental Rubber Works (L)
Continental-Diamond Fibre Corp., Div. of Budd Co. (J)
Contour Extrusion Co. (J)
Dryden Rubber Div., Sheller Mfg. Corp. (L)
Eberhard Faber Pencil Co. (L)
Extruder, Inc. (J)
Frost Rubber Co. (L)
Geauga Industries Co. (J, L)
General American Transportation Corp. (J)
General Plastics Corp. (J)
Gering Products, Inc. (J)
Glass Laboratories (J)
Goodrich, B. F. Industrial Products Co. (J)

Bold face indicates supplier advertises product in this issue

Gotham Plastics Corp. (J)
H & R Industries (J)
Hall Mfg. Corp. (J)
Hartwell, H. N. & Son, Inc. (J)
Hawkeye Rubber Mfg. Co. (J)
Hewitt-Robins, Inc. (L)
Hungerford Plastics Corp. (L)
Hydrawlik Co. (J, L)
Industrial Plastics Corp. (J)
Irvington Chemical Co. (J)
Irvington Varnish & Insulator Div., Minnesota Mining & Mfg. Co. (J)
Jet Specialties Co., Inc. (J)
Johnson Plastic Corp. (J, L)
Johnson Rubber Co. (L)
Joymont Plastics, Inc. (J)
Judsen Rubber Works, Inc. (L)
KSH Plastics, Inc. (J)
Kaykor Industries, Inc. (J)
Keystone Plastics, Inc. (J)
Kraloy Plastic Pipe Co., Inc. (J)
Luminous Resins, Inc. (J)
Luzeane Rubber Co. (L)
Mayon Plastics (J)
Mechanical Rubber Products Co. (K)
Meyer, J. & Sons, Inc. (J)
Mid-States Rubber Products, Inc. (L)
Midwest Plastic Products Co. (J)
Minnesota Rubber & Gasket Co. (L)
Moldex (L)
National Tube Div., U.S. Steel Corp. (J)
National Vulcanized Fibre Co. (J)
New England Tape Co., Inc. (J)
Panelyte Div., St. Regis Paper Co.
Parker, Stearns & Co., Inc. (L)
Pawling Rubber Co. (J)
Perfex Plastics, Inc. (J)
Plastex Co. (J)
Plastic Packaging Co. (J)
Plastic Process Co., Inc. (J)
Poly Plastic Products, Inc. (J)
Polyform Plastics Corp. (J)
Polymer Corp. (J)
Prima Pipe Co. (J)
Prince Rubber Co., Inc. (J, L)
Pyramid Plastics, Inc. (J, L)
Quaker Rubber Div., H. K. Porter Co. (J, L)
Raybestos-Manhattan, Inc. (K, L)
Reliance Plastic & Chemical Corp. (J)
Resin Industries (J)
Resistoflex Corp. (J)
Rex Corp. (J)
Robot Devices Inc. (J)
Rogers Corp. (L)
Rowland Products, Inc. (J)
Schwab Plastics Corp. (J, L)
Seamless Rubber Co. (L)
Shamban, W. S. & Co. (J)
Southern Plastics Co. (J)
Stalwart Rubber Co. (L)
Standard Products Co. (L)
Stockwell Rubber Co., Inc. (L)
Sun Rubber Co. (L)
Sunlite Plastics, Inc. (J)
Supplex Co., Div. of American Hard Rubber Co. (J, L)
Technical Specialties Co. (L)
Tri-Point Mfg. & Developing Co. (J)
U.S. Gasket Co. (J)
U.S. Rubber Co., Mechanical Goods Div. (J)
U.S. Stoneware Co. (J)
Victory Plastics Co. (J)
Vogt Mfg. Corp. (J)
Vulcanized Rubber & Plastics Co. (L)
Westlake Plastics Co. (J)
World Plastex (J, L)

FABRICS, NONWOVEN SYNTHETIC

American Felt Co.
Chicopee Mills, Inc.
Dexter, C. H. & Sons, Inc.
Felters Co.
Filpaco Industries, Inc.
Kendall Mills, Inc.
Troy Blanket Mills
U.S. Plywood Corp.
Visking Corp., Fabrics Div.
Wellington Sears Co., Sub. of West Point Mfg. Co.

FELTS, SYNTHETIC (see Fabrics)

FELTS, WOOL

Aetna Felt Co.
Allied Felt Corp.
American Felt Co.
Artex Felt Co.
Bacon Felt Co.
Beckmann, Inc.
Boston Felt Co.
Central Felt & Fabrics Corp.
Coated Abrasive Products, Inc.
Continental Felt Co.
Felters Co.
Fidelity Felt & Mfg. Co.
Filpaco Industries, Inc.
Mechanical Felt & Textiles Co.
National Felt Co.
Quaker City Felt Co.
Standard Asbestos Mfg. Co.
Standard Felt Co., Div. of Huntington Land and Improvement Co.
Supreme Industrial Products Co.
Western Felt Co.

FERRITES (see Ceramics)

FIBERS, SYNTHETIC
(see specific polymer)

FILM (see specific plastic or rubber)

FLUOROCARBON PLASTICS

Acme Resin Corp. (17)
Allegheny Plastics, Inc. (12, 13, 14)
Allied Chemical and Dye Corp., General Chemical Div. (17)
Auburn Plastic Engineering Co. (12, 13, 14)
Bakelite Co., Div. of Union Carbide Corp. (17, 22)
Bamberger, Claude P. Inc. (22)
Cadillac Plastic & Chemical Co. (20, 12, 13, 14)
Dixon Corp. (12, 13, 14)
du Pont de Nemours, E. I. & Co., Inc. (17, 19, 22)
Firestone Plastics Co. (17)
H & R Industries (20, 12, 14)
Minnesota Mining & Mfg. Co. (22)
Polymer Corp. (20, 12, 13, 14)
Raybestos-Manhattan, Inc., Plastic Products Div. (12, 13, 14)
Resistoflex Corp. (12, 13)
Shamban, W. S. & Co. (12, 13, 14)
Sparta Mfg. Co., Div. of U.S. Ceramic Tile Co. (20, 21, 12, 13, 14)
Thombert, Inc. (20, 12, 13, 14)
Tri-Point Mfg. & Developing Co. (12)
U.S. Gasket Co., Div. of Garlock Packing Co. (2, 9, 12)
U.S. Stoneware Corp. (13)
Visking Co., Plastics Div. (20)
Westlake Plastics Co. (12, 13, 14, 20)

FLUOROCARBON RUBBER
(Fluoroelastomers)

Continental Rubber Works (22, 12, 13, 14)
Dow Corning Corp. (17)
du Pont de Nemours, E. I. & Co., Inc. (17)
Hooker Electrochemical Corp. (17)
Johns-Manville Corp., Dutch Brand Div. (13)
Minnesota Mining & Mfg. Co. (17)
Rogers Corp. (12, 13, 14, 21, 22)
Westlake Plastics Co. (12, 13, 14)

FOAMS (see specific plastic or rubber)

FOIL (see specific metal)

FORGINGS (see also Cold Headed Parts)

Abegg & Reinhold Co. (F)
Accurate Brass Corp. (B)
Alco Products, Inc. (F)
Allegheny Ludlum Steel Corp. (F)
Aluminium Ltd. Sales, Inc. (A)
Aluminum Co. of America (A, D)
Amalgamated Steel Corp. (F)
American Brake Shoe Co.
American Brass Co. (B)
American Chain & Cable Co. (F)
American Manganese Bronze Co. (B)
American Steel Foundries (F)
AmForge Div., American Brake Shoe Co. (E, F)
Ampco Metal, Inc. (B)
Anti-Corrosive Metal Products Co., Inc. (F)
Auld, D. L. Co. (A)
Baldt Anchor, Chain & Forge Div., Boston Metals Co. (A, B, F)
Bay City Forge Co. (F)
Bethlehem Steel Co. (F)
Billings & Spencer Co. (A, B, F, G)
Blakeslee Forging Co. (A, B, C, D, E, F, G)
Bohn Aluminum & Brass Corp. (A)
Brewer-Titchener Corp. (A, F)
Bridgeport Brass Co. (A, G)
Bristol Brass Corp. (A)
California Drop Forge Co. (F)
Cameron Iron Works, Inc. (A, B, D, E, G, H)
Carbo Tool & Die Co.
Carpenter Steel Co. (E, F)
Champion Rivet Co. (B, C, E, F)
Chase Brass & Copper Co., Inc. (B)
Chicago Extruded Metals Co. (B)
Cincinnati Forging Co. (B)
Clapp, E. D. Mfg. Co. (B, C, E, F)
Cleveland City Forge Co. (C, F)
Cleveland Hardware & Forging Co. (F)
Columbus Bolt & Forging Co. (F)
Commercial Shearing and Stamping Co. (F)
Composite Forgings, Inc. (F)
Crucible Steel Co. of America (F, G)
Curtiss-Wright Corp. (F, G)
Cyril Bath Co. (A, F)
Dirilyte Co. of America, Inc. (A, B)
Electric Materials Co. (B)
Electric Steel Foundry Co. (E, F)
Endicott Forging & Mfg. Co., Inc. (B, E, F)
Eureka Electrical Products Co. (A, B, F)
Giant Grip Mfg. Co. (A, F, G)
Greene, G. G. Corp. (F)
Harvey Aluminum Div., Harvey Machine Co., Inc. (A, G)
Harvey Metal Corp. (A, B)
Heppenstall Co. (F, G)
Hobbs, Clinton E. Co. (C, F)
Hunter Douglas Aluminum Corp. (A, B)
Huron Forge & Machine Co. (A, B, F)
Illinois Forge, Inc. (F)
Illinois Iron & Bolt Co. (F)
Indiana Forge & Machine Co. (F)
International Nickel Co., Inc. (E)
Isaacson Iron Works (F)
Kaiser Aluminum & Chemical Sales, Inc. (A)
Keystone Forging Co. (F)
Kovar, John R. Mfg. Co., Inc. (F)
Kropp Forge Co. (F, G)
Ladish Co., (E, F, G)
Larson, Charles E. & Sons Inc. (B, C, F, G)
Larson Tool & Stamping Co. (A, B, C, D, E, F, G, H)
Latrobe Steel Co. (F)
Lenape Hydraulic Pressing & Forging Co. (A, B, F)
Lindell Drop Forge Co. (F)
Machinery Forging Co. (F)
Mallory, P. R. & Co., Inc. (B)

McCarter Iron Works Inc. (F)
McInnes Steel Co. (E, F, G)
McNally Pittsburg Mfg. Co. (F)
Melling Forging Co. (E)
Midvale-Heppenstall Co. (F)
Milwaukee Forge & Machine Co. (F)
Moore Dry Dock Co. (F)
Mueller Brass Co. (A, B)
Murray Tube Works, Inc. (A, B, F)
National Supply Co. (F)
Norcross, C. S. & Sons Co. (F)
Ohio Forge & Machine Corp. (C, E, F)
Olderman Mfg. Corp. (A, B)
Olds Alloys Co. (B)
Pacific States Steel Corp. (F)
Park Drop Forge Co. (F)
Pattin Mfg. Co. (F)
Pettibone Mulliken Corp. (F)
Pittsburgh Forgings Co. (A, F)
Poor & Co., Canton Forge & Axle Works (F)
Rankin Forge Co. (C, F)
Revere Copper and Brass, Inc. (A, B)
Rhode Island Tool Co. (A, B, D, F)
Rockford Bolt & Steel Co. (F)
St. Pierre Chain Corp. (A, E, F)
Scovill Mfg. Co. (A, B)
Searjeant Metal Products Inc. (F)
Seltzer, George H. & Co. (F)
Sharpsville Steel Fabricators, Inc. (F)
Sherman & Reilly, Inc. (A, F)
Skookum Co., Inc. (F)
Standard Forge & Axle Co., Inc. (F)
Standard Steel Works, Div. of Baldwin-Lima-Hamilton Corp.
Steel Improvement and Forge Co. (A, F)
Steel, R. & Sons, Inc. (F)
Titan Metal Mfg. Co. (A, B)
Tool & Mfg. Co., Inc. (F)
Transue-Williams (E, F, G)
Tube Turns, Inc. (A, B, C, E, F, G)
Union Forging Co. (F)
United Forge Co. (B, F)
U.S. Steel Corp. (F)
Vanadium-Alloys Steel Co. (F)
Walker Forge, Inc. (F)
Weber-Knapp Co. (A)
Wilcox Forging Corp. (B, F)
Wilde Drop Forge & Tool Co., Inc. (F)
Williams, J. H. & Co. (A, B, C, D, E, F)
Wyman-Gordon Co. (A, D, E, F, G)

FORMED METAL SHAPES (drawn, pressed or rolled; see also Stamping)

Accurate Metal Weather Strip Co., Inc. (A, B, C, F, H)
Ace Metal Spinning (A, B, C, D, E, F, G, H)
Ackermann Mfg. Co., Sub. of Wheeling Steel Corp. (F)
Acme Mfg. & Gasket Co. (A, B, E, F)
Acme Metal Spinning, Inc. (A, B, C, D, E, F, H)
Acme Stamping & Mfg. Co. (A, B, C, D, E, F)
Acro Metal Stamping Co. (A, B, E, F)
Adams, I. G. Metalware Co. (A, B, C, E, F)
Alco Products, Inc. (F)
Alloy Products Corp. (F)
Almco Steel Products Corp. (A, B, C, F)
Alpha Products, Inc. (A, F)
Aluminum Co. of America (A, D)
Aluminum Goods Mfg. (A, F)
Aluminum Specialty Co. (A)
American Kitchens Div., Avco Mfg. Corp. (F)
American Sheet Metal Works, Inc. (A, B, F)
American Silver Co., Inc. (A, B, D, E, F)
American Stamping Co. (A, B, F)
Ampco Metal, Inc. (B)
Anchor Metal Spinning (A, C, F)
Anderson, O. L. Co., Inc. (A, B, C, D, E, F, G, H)
Anderson-Bolling Mfg. Co. (A, F)
Anthes Force Oiler Co. (A, F)
Art Wire & Stamping Co. (A, B, C, D, E, F, G, H)
Associated Spring Corp. (F)
Auld, D. L. Co. (A, B)
Barclay Mfg. Co. (C)
Bartlett-Thompson Co., Inc. (A, B, E, F)
Bay State Tool & Machine Co. (F)
Behringer Metal Works, Inc. (A, B, C, F, H)
Belmet Products, Inc. (A, B, F)
Belmont Smelting & Refining Works, Inc. (H)
Benjamin Electric Mfg. Co. (F)
Bergfels, William & Co. (B, C, E, F, H)
Bethlehem Steel Co. (F)
Biersach & Niedermeyer Co. (A, B, C, E, H)
Blacher Bros., Inc. (B, F)
Bossert Div., Rockwell Spring & Axle Co. (A, B, F)
Brandt, Charles T. Inc. (A, B, C, E, F)
Brasco Mfg. Co. (A, B, C, E, F, H)
Broadway Mfg. Co. (A, B, C, F)
Brooks & Perkins, Inc. (A, D, G)
Burkhardt Steel Co. (F)
Campbell, A. S. Co., Inc. (A, F)
Carpenter Steel Co. (F)
Central Fabricators, Inc. (A, B, C, E, F, G)
Chase Brass & Copper Co. (B)
Cleveland Hardware & Forging Co. (F)
Cleveland Welding Div., American Machine & Foundry Co. (E, F, G)
Cly-Del Mfg. Co., Inc. (A, B, E, F, H)
Cold Metal Products Co. (F)
Columbus Bolt & Forging Co. (A, B, F)
Combined Industries Co. (A, B, C, D, E, F)
Commercial Shearing and Stamping Co. (A, E, F)
Conner Steel Products (A, F)
Continental Nu-Steel Metal Products Co. (A, F)
Cooley, W. J. & Co. (A, B, F)
Craft Mfg. Co. (A, B, C, D, E, F, G, H)
Crucible Steel Co. of America (F, G)
Cuyahoga Stamping Co. (A, B, F)
Cyril Bath Co. (A, D, E, F, G)
Darby Corp. (A, E, F)
Dare Products, Inc. (F)
Day Co. (A, F)
Detroit Stamping Co. (A, B, F)
Dolin Metal Products, Inc. (A, F)
Dow Chemical Co. (D)
Duplex Mfg. Corp. (A, F)
Eastern Tool & Mfg. Co. (A, B, F)
Electric Steel Foundry Co. (F)
Emerson-Sack-Warner Corp. (A, B, C, D, E, F, G, H)
Enamel Products Co. (A, F)
Etched Products Corp. (A, B, F)
Falstrom Co. (A, B, D, F)
Farwell Metal Fabricating (A, B, D, E, F)
Figley Die & Stamping Co. (A, B, F)
FitzSimons Mfg. Co. (A, B, F)
Franklin Steel Div., Borg-Warner Corp. (F)
Frasse, Peter A. & Co., Inc. (A, F)
Fuller, W. P. & Co. (H)
Garco Mfg. Co., Inc. (A, B, C, D, E, F, G, H)
General Alloys Co. (A, B, C, E, F)
General Plate Div., Metals & Controls Corp. (A, B, C, D, E, F, G, H)
Geometric Stamping Co. (A, B, F)
Gerstenslager Co. (A, F)
Geuder, Paeschke & Frey Co. (A, B, C, F)
Grammes, L. F. & Sons, Inc. (A, B, C, F)
Greene, G. G. Corp. (A, F)
Guarantee Specialty Mfg. Co. (A, B, C, F, H)
Guilfoy Cornice Works (A, B, C, F, H)
H & H Tube & Mfg. Co. (B)
Hawkridge Bros. Co. (A)
Hoofer Mfg. Co. (A, F)
Houston Blow Pipe & Sheet Metal Works (A, B, F)
Hydroforming Co. of America (A, B, F)
Ideal Can Co. (A, B, F)
Illinois Zinc Co., Div. of Hydrometals, Inc. (H)
Indus Corp. (A, F)
Inland Steel Co. (F)
Irvington Form & Tank Corp. (A, B, F)
Jackson Auto Radiator (A, B, F)
Jackson Steel Products, Inc. (A, B, E, F, H)
Jones & Laughlin Steel Corp. (F)
Judd Industries, Inc. (A, B, F)
Kees, F. D. Mfg. Co. (A, B, C, F)
Keystone Drawn Steel Co. (F)
Kling Metal Spinning & Stamping Co. (A, B, C, D, E, F, H)
Kroh Wagner (A, F, H)
Krueger & Hudepohl Inc. (A, B, C, E, F)
Lakewood Metal Products, Inc. (A, B, D, E, F, H)
Latrobe Steel Co. (F)
Lawrence, L. Co., Inc. (A, B, C, D, E, F, G, H)
Laystrom Mfg. Co. (A, B, C, E, F, H)
Leach & Garner Co., Industrial Div. (A, B, E)
Leake Stamping Div., Monarch Products Co. (A, B, E, F, G)
Legion Utensils Co. (B, E, F)
Lenape Hydraulic Pressing & Forging Co. (A, B, F)
Lincoln Steel Corp. (F)
Lockport Mfg. Co. (F)
Lockport Steel Fabricators, Inc. (A, E)
Lynn, Gary Co. (A, B, F)
Magnesium Co. of America (D)
Mahon, R. C. Co. (A, F)
Makepeace, D. E. Co. (A, B, E, F)
Matthiessen & Hegeler Zinc Co. (H)
Mayville Metal Products Co. (A, B, F)
McDowell Mfg. Co. (A, B, F)
McKinney Mfg. Co. (A, B, D, E, F)
Mechanical Steel Tubing Corp. (A, B, C, D, E, F, G, H)
Melco Wire Products (A)
Merrimac Brass (E)
Metal Forming Corp. (A, B, C, D, E, F, G, H)
Metal Parts & Stamping Co. (A, B, C, E, F, G, H)
Midvale-Heppenstall Co. (F)
Milwaukee Stamping Co. (A, F)
Missouri Boiler & Sheet Iron Works (F)
Moore Dry Dock Co. (F)
Morrison Steel Products, Inc. (F)
Morse, Fred W. Co. (A, B, F)
Narragansett Boiler Works, Inc. (F)
National Aluminum Co. (F)
National Moldite Co. (C)
New England Brass Co. (B)
Nichols, L. O. & Son Mfg. Co. (A, B, C, E, F, H)
Nichols Wire & Aluminum Co. (A)
Noera Mfg. Co. (A, B, F)
Norcross, C. S. & Sons Co. (F)
Ormond Mfg. Co., Inc. (A, B, C, E, F, H)
Parish Pressed Steel Div., Dana Corp. (A, F, G)
Parker, Charles Co. (A, F)
Pemco Wheel Co. (F)
Perrin, Edward C. Co. (A, B, F)
Peterson Products Corp. (A, B, E, F)
Phoenix Products Co. (A, B, C, E, F, G)
Pierce Governor of Ohio Inc. (A, F)
Pittsburgh Steel Corp. (B, C, E, F, H)
Pittsburgh Tool Steel Wire Co. (F)
Powell Pressed Steel Co. (A, F)
Precision Extrusions, Inc. (A)
Premier Metal Works, Inc. (A, B, E, F)
Pressed Steel Tank Co. (A, B, F)
Presswork Inc. (A, B)
Pyramid Moulding Inc. (F)
Rathbone Corp. (A, B, C, E, F)
Regal Ware, Inc. (A, B, F)
Republic Steel Corp. (A, B, F, G)
Reynolds Metals Co. (A)
Roll Formed Products Co. (A, B, D, F, H)

Rolock, Inc. (E)
Ryerson, Joseph T. & Son, Inc. (A, F)
Scovill Mfg. Co. (A, B, F)
Seattle Boiler Works, Inc. (A, E, F)
Servwell Products Co. (B, F)
Shank Metal Products Co. (A, F)
Sheffield Div. Armco Steel Corp. (F)
Spincraft, Inc. (A, B, F)
Stainless Metals, Inc. (F)
Standard Steel Sections, Inc. (A, C, F)
Standard Steel Works, Div. of Baldwin-Lima-Hamilton Corp. (F)
Steel Heddle Mfg. Co. (A, B, C, D, E, F)
Steel Industries, Inc. (F)
Stenman, Bror F. (A, B, F)
Stimpson, Edwin B. Co., Inc. (A, B, E, F, H)
Stover Steel Tank & Mfg. Co. (F)
Stulz-Sickles Co. (F)
Teiner, Roland Co., Inc. (A, B, C, E, F, G)
Textile Shield Co., Inc. (A, B, F)
Titan Metal Mfg. Co. (B)
Titanium Metal Corp. of America (G)
Toledo Stamping & Mfg. Co. (A, B, F)
Torngren, C. W. Co., Inc. (A, B, C, D, E, F, G)
Trojan Steel Co. (F)
Trussbilt, Div. Siems Bros., Inc. (E)
U.S. Steel Corp. (F)
Van Huffel Tube Corp. (A, B, F)
Vanadium-Alloys Steel Co. (F)
Victor Steel Products Corp. (F)
Vulcan Metal Products, Inc. (A)
Wabash Metal Products Co. (A, F, G)
Wall, P. Mfg. Co. (A, B, F)
Ward, H. H. Co. (A, B, E, F, H)
Warren Bros. Roads Co. (A, F)
Waterbury Buckle Co. (A, F, H)
Waterman Industries, Inc. (A, B, F)
Welding Apparatus Co. (A, E, F)
Werner, R. D. Co., Inc. (A, F)
Wesco Spring Co. (A, B, F)
Western Tool & Die Works (A, B, F)
Whitehead Metal Products Co., Inc. (A, B, E, F)
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp. (A, B, E, F, G)
Wilder Mfg. Co., Inc. (A, B, C, F)
Williams, F. B. (F)
Wirth, Carl & Son, Inc. (A, B, C, F)
Wolverine Tube Div., Calumet & Hecla, Inc. (A)
Wood, John Co. (F)
Woolf Aircraft Products, Inc. (A, B, F)
Worcester Pressed Steel Co. (A, B, C, D, E, F, G, H)
Worcester Stamped Metal Co. (A, B, E, F, G, H)
Worth Co. (A, B, F)
Wyckoff Steel Co. (F)
Youngstown Kitchens Div., American Standard Co. (A, F)
Youngstown Mfg., Inc. (A, F)

FORSTERITE (see Ceramics)

FURANES

Booty Resineers, Inc. (17)
Catalin Corp. of America (17)
Durez Plastics Div., Hooker Electrochemical Co. (17)
Furane Plastics Inc. (17, 18)
Knight, Maurice A. (17)
Loven Chemical of California (17)
Plastics Engineering Co. (17)
Reichhold Chemicals, Inc. (17)

GALVANIZED METALS

(see Precoated Metals)

GERMANIUM

American Metal Co., Ltd. (8, 10)
Belmont Smelting & Refining Works, Inc. (10)
Eagle-Picher Co. (8, 10)
Sylvania Electric Products, Inc. (8)

GLASS—FORMS AND PARTS

(No key indicates custom parts only)

Alox Mfg. Co.
Applied Instruments, Inc. (9, 12, 13)
Auto Glass Mfg. Co. (9, 13)
Bassichis Co. (10)
Bausch & Lomb Optical Co.
Binswanger & Co. (9, 13)
Chemiglas, Inc. (19)
Corning Glass Works (9, 10, 12, 13, 23)
Dodge Fibers Corp. (19)
Eagle Convex Glass Specialty Co. (13)
Edna Lite Optical Co., Inc. (21, 12, 13)
Erie Scientific Corp. (9, 13)
Ferro Corp. (19)
Fiber Glass Industries, Inc. (19)
Fischer & Porter Co. (12)
Fish-Schurman Corp. (19, 9, 10, 12, 13, 23)
Forman, Ford & Co. (9)
Friedrich & Dimmock, Inc. (12, 23)
Glass Laboratories Inc. (23)
Gustin-Bacon Mfg. Co. (19)
Houze Glass Corp. (19, 13)
Industrial Tectonics, Inc.
L.O.F. Glass Fibers Co. (19)
Lamtex Industries, Inc. (23)
Lancaster Glass Corp.
Libbey-Owens-Ford Glass Co.
Owens-Corning Fiberglas Corp. (19)
Owens Illinois Glass Co.
Penberthy Instrument Co. (13)
Pittsburgh Corning Corp.
Pittsburgh Plate Glass Co. (19, 9, 13)
Polacoat Inc. (13)
Pyrosil, Inc. (9, 10, 23)
Semon Bache & Co. (4, 9, 12, 13, 23)
Shull Bros. Glass Co. (23)

GLASS—FOR PLASTICS REINFORCEMENT

Exeter Mfg. Co.
Ferro Corp.
Fiber Glass Industries, Inc.
Flexfirm Products
Flightex Fabrics, Inc.
Fry Plastics Co.
Hess, Goldsmith & Co., Inc.
L.O.F. Glass Fibers Co.
Menardi & Co.
Omni Products Corp.
Owens-Corning Fiberglas Corp.
Pittsburgh Plate Glass Co.
Seaman Products
Texas Glass Fiber Corp.

GOLD AND ITS ALLOYS

Alpha Metals, Inc. (7)
American Metal Co., Ltd. (8)
American Platinum Works (9)
American Silver Co., Inc. (7, 14)
Baker & Co., Inc. (1, 2, 7, 8, 9, 10, 12, 13, 14)
Eastern Smelting & Refining Corp. (10)
General Plate Div., Metals & Controls Corp. (1, 7, 9, 12, 13, 14)
Goldsmith Bros., S. & R. Co. (1, 8, 9, 10, 12, 13, 14)
Hagstoz, T. B. & Son (1, 2, 9, 12)
Handy & Harman (1, 2, 7, 8, 9, 10, 12, 13, 14)
Hanovia Chemical & Mfg. Co. (10)
Leach & Garner Co., Industrial Div. (1, 2, 3, 7, 9, 12, 13, 14)
Metals Disintegrating Co., Inc. (10)
Ney, J. M. Co. (12, 13, 14)
Peerless Roll Leaf Co., Inc. (7, 14)
Sel-Rex Corp. (1, 10)
Western Gold & Platinum Co. (1, 7, 10, 12, 13, 14)
Wildberg Bros. Smelting & Refining Co. (1, 2, 3, 7, 8, 9, 10, 12, 13, 14)
Williams Gold Refining Co., Inc. (1, 2, 3, 7, 8, 9, 12, 14)

GRAPHITE (see Carbon)

GRAY IRON (see Iron)

GR-S RUBBER

(see Styrene-Butadiene Rubber)

HARD FACING ALLOYS

Air Reduction Sales Co.
Alloy Rods Co.
All-State Welding Alloys Co., Inc.
American Manganese Steel Div., American Brake Shoe Co.
Arcos Corp.
Champion Rivet Co.
Cleveland Hard Facing Co., Inc.
Fansteel Metallurgical Corp.
General Electric Co.
Harnischfeger Corp.
Hayden Wire Works Inc.
Haynes Stellite Co., Div. of Union Carbide Corp.
Hobart Bros. Co.
Lincoln Electric Co.
Marquette Mfg. Co., Inc.
McKay Co.
Metal & Thermit Corp.
Metallizing Co. of Los Angeles Inc.

KEY

MATERIALS

A—Aluminum and its alloys
B—Copper and its alloys
C—Iron and its alloys (except steel)
D—Magnesium and its alloys
E—Nickel and its alloys
F—Steels
G—Titanium and its alloys
H—Zinc and its alloys
J—Thermoplastics
K—Thermosetting plastics
L—Elastomers

BASIC FORMS

1—Anodes
2—Bar
3—Billets
7—Foil
8—Ingot
9—Plate
10—Powder
12—Rod
13—Sheet
14—Strip
17—Base resins, polymers or gums
18—Laminating or casting resins
19—Fibers or filaments
20—Film
21—Foams (component materials or products)
22—Molding compounds
23—Tube, nonmetallic (except plastics or rubber)

Republic Steel Corp.
Reynolds Mfg. Co.
Wall Colmonoy Co.

HIGH PRESSURE LAMINATES
(see Laminates)

HYPALON
(see Chlorosulfonated Polyethylene Rubber)

IMPACT EXTRUSIONS
(cold extrusions)

Aluminum Co. of America (A)
Cliff Mfg. Co. (A)
Curtiss-Wright Corp. (F)
Cyril Bath Co. (A, F)
Dow Chemical Co. (D)
Harvey Aluminum Div., Harvey Machine Co., Inc. (A, G)
Heintz Mfg. Co. (F)
Hunter-Douglas Aluminum Div., Bridgeport Brass Co. (A)
Impax, Inc. (A, B, D, H)
Leake Stamping Div., Monarch Products Co. (A, F)
Magline, Inc. (D)
Magnesium Co. of America (D)
Rockwell Spring & Axle Co. (F)
Sun Tube Corp. (A, B, D)
Worcester Pressed Steel Co. (A)

INDIUM AND ITS ALLOYS

Alpha Metals, Inc. (2, 3, 7, 8, 12, 13, 14)
Belmont Smelting & Refining Works, Inc. (2, 8)
Cerro de Pasco Sales Corp. (8)
Division Lead Co. (2)
Federated Metals Div., American Smelting & Refining Co. (2, 3, 7, 8, 12, 13, 14)
General Plate Div., Metals & Controls Corp. (14)
Indium Corp. of America (2, 8, 10)
Peerless Roll Leaf Co., Inc. (7, 14)
Sel-Rex Corp. (10)
Western Gold & Platinum Co. (12, 13, 14)
Williams Gold Refining Co., Inc. (1, 2, 3, 7, 8, 9, 10, 12, 14)

INGOTS (see specific metal)

INJECTION MOLDINGS
(see Moldings)

INTERMETALLIC COMPOUNDS
(see Ceramics)

INVESTMENT CASTINGS
(see Castings)

IRON, ALLOY (castings)

Advance Foundry Co.
Alloy Precision Castings Co.
American Cast Iron Pipe Co.
American Foundries Co.
Apex Steel Corp., Ltd.
Arzt, T. L. Foundry Co.
Atlantic Foundry Co.
Beaver Valley Alloy Foundry Co.
Blackmer Pump Co.
Bonnot Co.
Butler Engine & Foundry Co., Inc.
Cadillac Malleable Iron Co.
Calumet Div., Calumet & Hecla, Inc.
Campbell, Wyant and Cannon Foundry Co., Div. of Textron, Inc.
Carondelet Foundry Co.
Casting Service Corp. of Michigan
Chemung Foundry Corp.
Chicago Hardware Foundry Co.
Cleveland Foundry & Mfg. Co., Inc.
Crawford & Doherty Foundry Co.
Curtiss-Wright Corp.
Dalton Foundries, Inc.
Dayton Foundry
Electric Steel Foundry Co.
Electron Corp.
Florence Pipe Foundry & Machine Co.
Flynn & Emrich Co.
Frederick Iron & Steel, Inc.
Gale Mfg. Co.
Gillett & Eaton, Inc.
Gunite Foundries Corp.
H & H Foundry Machine Co.
Hamilton Foundry & Machine Co.
Helmick Foundry-Machine Co.
Irwin Foundry and Mine Car Co., Industrial and Furnace Car Div.
Janney Cylinder Co.
Keen Foundry Co., Inc.
Kingsport Foundry & Mfg. Corp.
Kutztown Foundry and Machine Corp.
Lake Erie Foundry Co.
Lang-Scharmann & Co.
Lincoln Foundry Corp.
Littlestown Hardware & Foundry Co., Inc.
Long Beach Iron Works
Macaulay, H. C. Foundry Co.
Mackintosh-Hemphill Div., E. W. Bliss Co.
Manufacturers Iron Foundry, Inc.
McLanahan & Stone Corp.
Meehanite Metal Corp.
Midwestern Foundries, Inc.
Montague Machine Co.
National Iron Co.
North Wales Foundry Co., Inc.
Oakland Foundry & Machine Co.
Oil City Iron Works
Pittsburgh Foundry & Machine Co.
Potts, C. & G. & Co.
Prescott Co.
Quest, J. F. Foundry Co.
Republic Steel Corp.
Rosedale Foundry & Machine Co.
Ross-Meehan Foundries
St. Marys Foundry Co.
Schneider Bowman Co., Inc.
Sheffield Foundry Co.
Sibley Machine & Foundry Corp.
Sioux City Foundry & Boiler Co.
Springfield Foundry Co.
Spuck Iron & Foundry Co.
Standard Foundry Co.
Stuart Foundry Co.
Taylor & Co., Inc.
Taylor & Boggis Foundry
Texas Foundries, Inc.
Tower Grove Foundry
Union Iron Works
Valley Iron Works, Inc.
Washington Iron Works
Waterman Industries, Inc.
Zenith Foundry

IRON, COMMERCIAL

Armco Steel Corp. (2, 3, 9, 13, 14)
Republic Steel Corp. (8)

IRON, GRAY (castings)

ACF Industries, Inc., American Car & Foundry Div.
Acme Foundry & Machine Co.
Advance Foundry
Albert Lea Foundry Co.
Allegheny Foundry Co.
Allis-Chalmers Mfg. Co.
Almont Mfg. Co.
American Brake Shoe Co.
American Cast Iron Pipe Co.
American Foundries Co.
American Foundry Co., Inc.
American Laundry Machinery Co.
Apex Steel Corp., Ltd.
Appleton Electric Co.
Arneson Foundry, Inc.
Arzt, T. L. Foundry Co.
Atlantic Foundry Co.
Atlas Foundry Co.
Auburn Foundry Inc.
Avco Mfg. Corp., New Idea Div.
Baldwin-Lima-Hamilton Corp.
Banner Iron Works
Barnett Foundry & Machine Co.
Belle City Malleable Iron Co.
Bethlehem Steel Co.
Black-Clawson Co.
Blackmer Pump Co.
Bonnot Co.
Brake Shoe & Castings Div., American Brake Shoe Co.
Bruce Foundry & Mfg. Co.
Butler Engine & Foundry Co., Inc.
Calumet Div., Calumet & Hecla, Inc.
Campbell, Wyant and Cannon Foundry Co., Div. of Textron, Inc.
Carondelet Foundry Co.
Casting Service Corp. of Michigan
Chemung Foundry Corp.
Chicago Hardware Foundry Co.
Cincinnati Foundry Co.
Cleveland Foundry & Mfg. Co., Inc.
Columbiana Pump Co.
Compton Foundry
Continental Gin Co.
Cooper-Bessemer Corp.
Crawford & Doherty Foundry Co.
Dalton Foundries, Inc.
Dayton Foundry
Decatur Casting Co.
Dodge Mfg. Corp.
Dostal Foundry & Machine Co.
Eaton Mfg. Co., Foundry Div.
Electro Metallurgical Co., Div. of Union Carbide Corp.
Electron Corp.
Elkhart Iron Works
Empire Pattern and Foundry Co.
Enterprise Wheel & Car Corp.
Florence Pipe Foundry & Machine Co.
Florin Foundry & Mfg. Co.
Flynn & Emrick Co.
Frederick Iron & Steel, Inc.
Fulton Foundry & Machines Co., Inc.
Gale Mfg. Co.
Gartland Haswell Foundry Co.
General Foundry & Mfg. Co.
General Iron Works Co.
General Motors Corp., Central Foundry Div.
Georgia Iron Works
Gillett & Eaton, Inc.
Glamorgan Pipe and Foundry Co.
Gowanda Furnaces, Inc.
Grafton Foundry Co.
Greenlee Foundry Co.
Gunite Foundries Corp.
H & H Foundry Machine Co.
Hamilton Foundry & Machine Co.
Hardinge Mfg. Co.
Helmick Foundry-Machine Co.
Independence Stove & Mfg. Co.
International Harvester Co.
International Nickel Co., Inc.
Irwin Foundry and Mine Car Co., Industrial and Furnace Car Div.
Janney Cylinder Co.
Johnstone Foundries, Inc.
Kanawha Mfg. Co.
Kansas City Hay Press Co.
Keen Foundry Co., Inc.
Kelly Foundry Co.
King-Seeley Corp.
Kingsport Foundry & Mfg. Corp.
Koehring Co.
Kutztown Foundry and Machine Corp.
LFM Mfg. Co., Inc.

Lake Erie Foundry Co.
Lang-Scharmann & Co.
LaPorte Foundry Co., Inc.
Laragy, P. Iron Foundry, Inc.
Lectromelt Casting Co.
Lehigh, Inc.
Lewistown Foundry & Machine Co.
Lincoln Foundry Corp.
Lincoln Iron Works
Link-Belt Co.
Littite Foundries Inc.
Littlestown Hardware & Foundry Co., Inc.
Lodge Mfg. Co.
Long Beach Iron Works
Macaulay, H. C. Foundry Co.
Madison Foundry Co.
MaGirl Foundry & Furnace Co.
Manufacturers Iron Foundry, Inc.
McCarter Iron Works Inc.
McLanahan & Stone Corp.
Meehanite Metal Corp.
Midwestern Foundries, Inc.
Montague Machine Co.
Morrisvill Foundry Co., Inc.
National Iron Co.
National Supply Co.
North Wales Foundry Co., Inc.
Oakland Foundry & Machine Co.
Oil City Iron Works
Palmyra Foundry Co., Inc.
Pequonnock Foundry, Inc.
Perkins, Henry Co.
Pittsburgh Foundry & Machine Co.
Pohlman Foundry Co., Inc.
Posey Iron Works, Inc.
Potts, C. & G. & Co.
Prescott Co.
Pusey & Jones Corp.
Quest, J. F. Foundry Co.
Refinery Castings Co.
Republic Steel Corp.
Riverside Foundry Co.
Rodney Hunt Machine Co.
Rosedale Foundry & Machine Co.
Ross-Meehan Foundries
St. Marys Foundry Co.
Schneider Bowman Co., Inc.
Selma Foundry & Machine Co.
Sharpsville Steel Fabricators, Inc.
Sheffield Foundry Co.
Shenango Furnace Co.
Sibley Machine & Foundry Corp.
Sioux City Foundry & Boiler Co.
Sonith Industries, Inc.
Southern Car & Mfg. Co., Inc.
Spring City Foundry Co.
Springer's Foundry Co., Inc.
Springfield Foundry Co.
Spuck Iron & Foundry Co.
Standard Foundry Co.
Stearns-Roger Mfg. Co.
Sterling Foundry Co.
Sterrit-Thomas Foundry Co.
Stuart Foundry Co.
Swett, A. L. Iron Works
Taylor & Boggis Foundry
Taylor & Co., Inc.
Terre Haute Malleable & Mfg. Corp.
Tower Grove Foundry
Union Iron Works
U.S. Pipe and Foundry Co.
Utica General Jobbing Foundry, Inc.
Valley Iron Works, Inc.
Vulcan Foundry Co.
Vulcan Rail & Construction Co.
Washington Iron Works
Waterman Industries, Inc.
Werner Foundry & Machine Co.
Western Foundry & Machine Works, Inc.
Western Iron & Foundry Co., Inc.
Westinghouse Electric Corp., Materials Mfg. Dept.
Wollaston Foundry Corp.
Woodruff & Edwards, Inc.
Yale & Towne Mfg. Co.
Zellner Foundry Co.
Zenith Foundry

IRON, MALLEABLE (castings)

Acme Steel & Malleable Iron Works
Albion Malleable Iron Co.
Alloy Precision Castings Co.
American Chain & Cable Co.
American Malleable Castings Co.
Appleton Electric Co.
Auto Specialties Mfg. Co.
Badger Malleable & Mfg. Co.
Belcher Malleable Iron Co.
Belle City Malleable Iron Co.
Cadillac Malleable Iron Co.
Chicago Malleable Castings Co.
Connecticut Malleable Castings Co.
Dayton Malleable Iron Co.
Eastern Malleable Iron Co.
General Electric Co., Foundry Dept.
General Motors Corp., Central Foundry Div.
Iowa Malleable Iron Co.
Jamestown Malleable Iron Corp.
Laconia Malleable Iron Co.
Lake City Malleable Co.
Lakeside Malleable Castings Co.
Lancaster Malleable Castings Co.
Lehigh, Inc.
Lincoln Foundry Corp.
Link-Belt Co.
McCarter Iron Works Inc.
Meeker Foundry Co.
Mitchell Metal Products, Inc.
Muncie Malleable Foundry Co.
National Malleable & Steel Castings Co.
Northern Malleable Iron Co.
Pratt, William E. Mfg. Co.
Republic Steel Corp.
St. Louis Malleable Castings Co.
Sharpsville Steel Fabricators, Inc.
Superior Steel & Malleable Castings Co.
Terre Haute Malleable & Mfg. Corp.
Texas Foundries, Inc.
U.S. Challenge & Challenge Co.
Vulcan Rail & Construction Co.
West Virginia Malleable Iron Co.
Westmoreland Malleable Iron Co.

IRON, NODULAR OR DUCTILE (castings)

Advance Foundry
American Cast Iron Pipe Co.
Atlantic Foundry Co.
Black-Clawson Co.
Bonnot Co.
Campbell, Wyant and Cannon Foundry Co., Div. of Textron, Inc.
Chicago Hardware Foundry Co.
Crawford & Doherty Foundry Co.
Curtiss-Wright Corp.
Electron Corp.
Gunite Foundries Corp.
Hamilton Foundry & Machine Co.
International Nickel Co.
Jamestown Malleable Iron Corp.
Janney Cylinder Co.
Kutztown Foundry & Machine Corp.
Meehanite Metal Corp.
Montague Machine Co.
Rosedale Foundry & Machine Co.
Ross-Meehan Foundries
Sioux City Foundry & Boiler Co.
Southern Car & Mfg. Co., Inc.

IRON, WROUGHT

Byers, A. M. (9)
Gary Steel Products Corp. (2, 9, 13)
Lockhart Iron & Steel Co. (2, 3)
Sharpsville Steel Fabricators, Inc. (9, 14)

IRON POWDERS

Alan Wood Steel Co.
Alloy Metal Powders, Inc.
Antara Chemicals Div., General Aniline & Film Corp.
Belmont Smelting and Refining Works
Easton Metal Powder Co.
Ekstrand & Tholand
Hardy, Charles, Inc.
Hoeganaes Sponge Iron Corp.
Johnson, A & Co., Inc.
Magnetic Powders, Inc.
Metal Hydrides, Inc.
Plastic Metals Div., National Radiator Co.
Pyron Corp.
Republic Steel Corp.
Vanadium-Alloys Steel Co.

ISOPRENE-ISOBUTYLENE RUBBER

Adhesive Products Corp. (18)
American Hard Rubber Co. (13)
Armstrong Cork Co. (12, 13, 14)
Brown Rubber Co., Inc. (21)
Continental Rubber Works (22, 12, 13, 14)
Enjay Co., Inc. (17)
Geauga Industries Co. (22, 12, 14)
Goodrich, B. F. Chemical Co. (17, 18, 22)
Goshen Rubber Co., Inc. (22)
Home Rubber Co. (22, 12, 13, 14)
Mid-States Rubber Products, Inc. (22, 13, 14)
Rand Rubber Co. (20, 13)
Roth Rubber Co. (22, 13)
Standard Products Co. (22)
Stockwell Rubber Co., Inc. (22, 13, 14)
Technical Specialties Co. (14)
Vulcanized Rubber & Plastics Co. (22)

LAMINATES

(see below; see also Pre-Impregnated Materials)

LAMINATES, HIGH PRESSURE, PLASTICS OR RUBBER

(sheet, rod or tube, incl clad laminates)

Acme Specialties, Inc. (J, K, L)
American Agile Corp. (J)
American Hard Rubber Co. (K, L)
Apex Reinforced Plastics Div., White Sewing Machine Corp. (K)
Auburn Plastic Engineering (J)
Cadillac Plastic & Chemical Co. (J, K)
Capac Industries, Inc. (K)
Commercial Plastics & Supply Corp. (K)
Conneaut Rubber and Plastics Co. (J, K, L)
Connecticut Hard Rubber Co. (L)
Conolite Div., Continental Can Co., Inc. (K)
Continental Rubber Works (L)
Continental-Diamond Fibre Corp., Div. of Budd Co. (K)
Davidson Rubber Co. (L)
Dryden Rubber Div., Sheller Mfg. Corp. (L)
Everlite Corp. (K)
Farley & Loetscher Mfg. Co., Plastics Div. (K)
Formica Corp. (K)
Gatke Corp. (K)
General Electric Co., Laminated & Insulating Products Dept. (K, L)
General Plastics Corp. (J)
General Tire & Rubber Co. (K)
H & R Industries (J)
Hartwell, H. N. & Son, Inc. (J)
Haskelite Mfg. Corp. (K)
Home Rubber Co. (L)
Iten Fibre Co. (K)
Kerr, R. W. Plastic Co. (J, K)
Lewis, J. P. Co., Plastic Products Div. (K)
Luminous Resins, Inc. (J)
Marblette Corp. (K)
Mechanical Rubber Products Co. (K)
Mica Insulator Co. (K)

Micarta Div., Westinghouse Electric Corp. (K)
National Vulcanized Fibre Co. (K)
New England Laminates Co., Inc. (J, K)
Panelyte Div., St. Regis Paper Co. (K)
Penn Fibre & Specialty Co., Inc. (K)
Philrus Products Co. (K)
Porter, William Co. (K)
Prince Rubber Co., Inc. (J)
Quaker Rubber Div., H. K. Porter Co. (J, L)
Ren Plastic, Inc. (K)
Replac Corp. (J, K, L)
Richardson Co. (K)
Rogers Corp. (K)
Shamban, W. S. & Co (J)
Spaulding Fibre Co., Inc. (K)
Standard Insulation Co. (K)
Synthane Corp. (K)
Taylor Fibre Co. (K)
Thombert, Inc. (K)
U.S. Polymeric Chemicals, Inc. (K)
Vulcanized Rubber & Plastics Co. (L)
Westlake Plastics Co. (K)

LAMINATES, LOW PRESSURE, PLASTICS OR RUBBER

(sheet, rod or tube, incl clad laminates)

Acme Specialties, Inc. (J, K, L)
Allegheny Plastics, Inc. (J)
Alsynite Co. of America (K)
American Agile Corp. (J)
American Hard Rubber Co. (K, L)
American Insulator Corp. (K)
Apex Reinforced Plastics Div., White Sewing Machine Corp. (K)
Auburn Plastic Engineering (K)
Biggs, Carl H. Co., Inc. (K)
Cadillac Plastic & Chemical Co. (J, K)
Capac Industries, Inc. (K)
Carroll, J. B. Co. (J)
Connecticut Hard Rubber Co. (L)
Continental Rubber Works (L)
Continental-Diamond Fibre Corp., Div. of Budd Co. (K)
Corite Products, Inc. (K)
Corrulux Div., L. O. F. Glass Fibers Co. (K)
Dura Plastics of New York, Inc. (J)
Frost Rubber Co. (L)
Gering Products, Inc. (J)
Glastic Corp. (K)
Haskelite Mfg. Corp. (K)
Hays Mfg. Co. (K)
Home Rubber Co. (L)
Kaykor Industries, Inc. (J)
Kerr, R. W. Plastic Co. (J, K)
Laminated Plas-Tex Corp. (J)
Lamtex Industries, Inc.
Lunn Laminates, Inc. (K)
Mechanical Rubber Products Co. (K)
Mica Insulator Co. (K)
Minnesota Mining & Mfg. Co. (K)
Molded Fiber Glass Sheet Co. (K)
National Vulcanized Fibre Co. (K)
New England Laminates Co., Inc. (J, K)
Porter, William Co. (K)
Prince Rubber Co., Inc. (J, L)
Rand Rubber Co. (J, K)
Ren Plastics, Inc. (K)
Replac Corp. (K, L)
Resolite Corp. (K)
Rowland Products, Inc. (J)
Rubber Corp. of America (J)
Russell Reinforced Plastics Corp. (K)
Sewell Mfg. Co. (J)
Shamban, W. S. & Co. (J)
Sparta Mfg. Co., Div. of U.S. Ceramic Tile Co. (J)
Standard Insulation Co. (K)
Stockwell Rubber Co., Inc. (J, L)
Stone Paper Tube Co. (K)
Strick Plastics Co. (J, K, L)
U.S. Polymeric Chemicals, Inc. (K)
U.S. Rubber Co. (J)
Urrite Plastics Fabricators (J)
Vulcanized Rubber & Plastics Co. (L)
Westlake Plastics Co. (K)

LAMINATES, HIGH OR LOW PRESSURE, PLASTICS OR RUBBER—MOLDINGS

(incl clad laminates)

Admiral Corp., Molded Products Div. (K)
American Agile Corp. (J)
American Hard Rubber Co. (J, K, L)
American Insulator Corp. (K)
Apex Reinforced Plastics Div., White Sewing Machine Corp. (K)
Arrowhead Products (K, L)
Artmor Plastics Corp. (K)
Bassons Industries, Corp. (K)
Cadillac Plastic & Chemical Co. (J, K)
Carroll, J. B. Co. (J)
Chemical Products Corp. (J)
Continental Rubber Works (L)
Continental-Diamond Fibre Corp., Div. of Budd Co. (K)
Corite Products, Inc. (K)
Eljay Corp. (K)
Englander Co., Inc., Plastics Div. (K)
Formica Corp. (J)
Foss Mfg. Co., Plastics Div. (K)
Frost Rubber Co. (L)
Gatke Corp. (K)
General Electric Co., Laminated & Insulating Products Dept. (K)
General Tire & Rubber Co. (K)
Glastic Corp. (K)
Haskelite Mfg. Corp. (K)
Hays Mfg. Co. (K)
Home Rubber Co. (L)
Kerr, R. W. Plastic Co. (J, K)
Lamtex Industries, Inc. (J, K)
Lunn Laminates, Inc. (J, K)
Mechanical Rubber Products Co. (K)
Mica Insulator Co. (K)
Micarta Div., Westinghouse Electric Corp. (K)
Minnesota Mining & Mfg. Co. (K)
Molded Fibre Glass Co. (K)
National Vulcanized Fibre Co. (K)
New England Laminates Co., Inc. (J, K)
Northwest Plastics Industries, Inc. (K)
Panelyte Div., St. Regis Paper Co. (K)
Plymouth Industrial Products, Inc. (J)
Porter, William Co. (K)
Quaker Rubber Div., H. K. Porter Co. (L)
Ren Plastics, Inc. (K)
Replac Corp. (J, K, L)
Resolite Corp. (K)
Richardson Co. (K)
Russell Reinforced Plastics Corp. (K)
Shamban, W. S. & Co. (J)
Sierra Electric Corp. (J, K)
Sparta Mfg. Co., Div. of U. S. Ceramic Tile Co. (J)
Spaulding Fibre Co., Inc. (K)
Standard Insulation Co. (K)
Stockwell Rubber Co., Inc. (J, L)
Strick Plastic Co. (J, K, L)
Sun Rubber Co. (L)
Synthane Corp. (K)
Thompson, H. I. Fiber Glass Co. (J)
Toledo Industrial Rubber Co. (K)
U.S. Polymeric Chemicals, Inc. (K)
Waterbury Companies, Inc. (K)
Wittman, Lawrence & Co. (K)
Zenith Plastics Co. (K)

LAMINATES, METAL-METAL

(key letters refer to base metal)

Almco Steel Products Corp. (C, F)
American Cast Iron Pipe Co. (C, F)
American Silver Co., Inc. (B, C, E, F)
Baker & Co. (B, E)
Bridgeport Brass Co. (B, C, E, F)
Chace, W. M. Co. (thermostatic bimetals)
Copperweld Steel Co. (F)
Eastern Brass & Copper Co. (A)
General Findings & Supply Co., Industrial Div. (B, E)
General Plate Div., Metals & Controls Corp. (A, B, C, D, E, F, G, H) (thermostatic bimetals)
Improved Seamless Wire Co. (B, C, E)
Knapp Mills, Inc. (B, F)
Laminated Shim Co. (A, B, F)
Leach & Garner Co., Industrial Div. (B, E)
Makepeace, D. E. Co. (B, E, G)
Staver Co., Inc. (A)
Sylvania Electric Products, Inc. (B, E)
Wilson, H. A. Co. (B, E, F)
Wisconsin Gasket & Mfg. Co. (B, F)

LAMINATES, METAL-ORGANIC

(key letters refer to base metal)

American Nickeloid Co. (A, F)
Arvin Industries (A, D, F)
Benjamin Electric Mfg. Co. (F)
Clad-Rex Corp. (A, F)
Coated Coil Corp. (A, F)
Cochran Foil Co. (A)
Hood Rubber Co., Div. of B. F. Goodrich Chemical Co. (A, F)
O'Sullivan Rubber Co. (F)
U. S. Steel Corp., Irvin Works (F)

LAMINATING RESINS

(see specific plastic or rubber)

LEAD AND ITS ALLOYS

Alpha Metals, Inc. (2, 3, 4, 7, 8, 9, 10, 12, 13, 14)
American Metal Co., Ltd. (2, 3, 8, 10, 12)
Belmont Smelting & Refining Works Inc. (1, 2, 7, 8, 9, 10, 13, 14)
Bunker Hill Co., Sales & Fabrication Div. (1, 2, 8, 9, 12, 13, 14)
Chicago Smelting & Refining Corp. (8)
Crown Metal Co. (1, 2, 7, 8, 9, 12, 13, 14)
Dietzel Lead Burning Co. (1, 2, 9, 13)
Division Lead Co. (1, 2, 3, 7, 8, 9, 10, 12, 13, 14)
Dixie Lead Co. (1, 2, 3, 8, 9, 10, 13)
Eagle-Picher Co. (10)
Evans Metal Co. (13)
Federated Metals Div., American Smelting & Refining Co. (1, 2, 3, 8, 9, 12, 13, 14)
Fox Products Co. (1)
General Plate Div., Metals & Controls Corp. (14)
Glidden Co. (10)
Goldsmith Bros., S. & R. Co. (2, 8)
Hayman, Michael & Co., Inc. (2, 8)
Hudson Smelting & Refining Co. (8)
Kirk, Morris P. & Son, Inc. (1, 2, 3, 8, 9, 10, 12, 13, 14)
Lavin, R. & Sons, Inc. (1, 8)
McGean Chemical Co. (1)
Metal & Thermit Corp. (1)
Metals Disintegrating Co., Inc. (10)
National Lead Co. (10)
National Lead Construction Co. (1)
New England Smelting Works, Inc. (2, 8)
Oatey, L. R. Co. (2, 8, 13, 14)
Olds Alloys Co. (3, 8)
Peerless Alloy Co. (1, 2, 3, 8, 9, 12, 13)
Peerless Roll Leaf Co., Inc. (7, 14)
Pittsburgh Smelting & Refining Co. (8)
Republic Lead Equipment Co. (1)
Republic Metals Co., Inc. (1, 2, 7, 8, 12, 13, 14)
River Smelting & Refining Co. (8)
Rotometals (2, 8, 10, 13)
St. Joseph Lead Co. (8)
U.S. Smelting, Refining & Mining Co. (2, 3, 8)
Waltham Foundry Co. (8)

LEATHER AND LEATHER PARTS

Alexander Bros. Belting Co.
Alexander, E. P. & Son
Auburn Mfg. Co.
Barnes, Henry K. Co.
Bond, Charles & Co.
Charlotte Leather Belting Co.
Chicago Rawhide Mfg. Co.
Donovan, F. C. Inc.
Gibb, Walton Leather Co.
Glenn, Joseph & Sons, Inc.
Graton & Knight Co.
Haffner Bros. Co.
Hay, James E. Leather Co.
Houghton, E. F. & Co.
Mechanical Leathers, Inc.
Michigan Leather Products Co.
Monarch Belting Co.
Norwich Leather Co.
Page Belting Co.
Porter, William Co.
Rees' Sons, Hans
Rhoads, J. E. & Sons
Schachner Leather & Belting Co.
Shingle Leather Co.
Southern Belting Co.
Special Leathers Co.
Standard Washer & Mat Inc.
Truche Leather Co.
Warren Belting Co.
Winworth Co., Inc.

LITHIUM

American Potash and Chemical Corp.
Foote Mineral Co.
Lithium Corp. of America

LOW PRESSURE LAMINATES

(see Laminates)

MAGNESIUM AND ITS ALLOYS

Aluminium Ltd. Sales, Inc. (8)
Aluminum Co. of America (1, 2, 3, 9, 12, 13, 14)
Aluminum & Magnesium, Inc. (8)
American Smelting & Refining Co. (1, 8)
Apex Smelting Co. (1, 8)
Armet Alloys, Inc. (8)
Belmont Smelting & Refining Works, Inc. (1, 8, 10)
Brooks & Perkins, Inc. (9, 13)
Dow Chemical Co. (1, 2, 8, 9, 10, 12, 13, 14)
Federated Metals Div., American Smelting & Refining Co. (1, 8)
Hardy, Charles, Inc. (10)
King Laboratories, Inc. (8, 10)
Magline, Inc. (9, 13)
Magna Mfg. Co., Inc. (10)
Magnode Products, Inc. (1)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (7, 8)
Peerless Roll Leaf Co., Inc. (7, 14)
Reade Mfg. Co., Inc. (10)
Standard Magnesium Corp. (1, 8)
U.S. Magnesium Co. (10)
Waltham Foundry Co. (8)
White Metal Rolling & Stamping Corp. (2, 9, 12)

MANGANESE AND ITS ALLOYS

Amalgamated Steel Corp. (2, 12)
Belmont Smelting & Refining Works, Inc. (8, 10)
Chicago Development Corp. (12, 13, 14)
Electro Metallurgical Co., Div. of Union Carbide Corp. (10)
Foote Mineral Co. (10)
Hardy, Charles Inc. (10)
Hommel, O. Co. (10)
Lavin, R. & Sons, Inc. (8)
Metals Disintegrating Co., Inc. (10)
National Paint & Manganese Co. (10)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (7, 8)
Pioneer Aluminum Inc. (9)
Plastic Metals Div., National-U.S. Radiator Corp., (10)
Reade Mfg. Co., Inc. (10)
Universal Castings Corp. (8)

MANGANESE BRONZE (see Copper)

MELAMINES

Adhesive Products Corp. (18)
American Cyanamid Co., Plastics & Resins Div. (17, 18, 22)
Barrett Div., Allied Chemical & Dye Corp. (22)
Catalin Corp. of America (17)
Commercial Plastics & Supply Corp. (12, 13, 14)
Consoweld Corp. (13)
Farley & Loetscher Mfg. Co., Plastics Div. (13)
Fiberite Corp. (22)
Formica Corp. (12, 13, 14)
Haskelite Mfg. Corp. (13, 14)
Mica Insulator Co. (12, 13)
Monsanto Chemical Co. (22, 17)
Muehlstein, H. & Co., Inc. (22, 17)
National Vulcanized Fibre Co. (12, 13)
Northern Plastics Corp. (13, 14)
Omni Products Corp. (22)
Philrus Products Co. (12, 13, 14)
Reichhold Chemicals, Inc. (17, 18)
Spaulding Fibre Co., Inc. (12, 13, 14)
Synthane Corp. (12, 13, 14)
Taylor Fibre Co. (12, 13)
Texas Glass Fiber Corp. (22)
Westlake Plastics Co. (12, 13, 14)

METAL POWDER PARTS

Allied Products Corp. (B, C, F)
Aluminum Co. of America (A)
American Brake Shoe Co. (A, B, C, E, F)
American Powdered Metals Inc. (A, B, C, E, F)
American Sinteel Corp. (A, B, C, E, F)
Amplex Div., Chrysler Corp. (A, B, C, E, F)
Arnold Engineering Co. (A, B, C, E, F)
Arrow Sintered Products Co. (C)
Asco Sintering Corp. (A, B, C, E, F)
Atlas Brass Foundry (B, C)
Bassick Co. (A, B, C, E, F)
Bendix Aviation Corp. (A, B, C, E, F)
Boston Gear Works (A, B, C, E, F)
Bound Brook Oil-Less Bearing Co. (B, C, E)
Brockway Pressed Metals, Inc. (A, B, C, E, F)
Bunting Brass & Bronze Co. (B, C)
Burgess-Norton Mfg. Co. (A, B, C, E, F)
Carbon City Products Co., Inc. (B, C)
Cero-Met (A, B, C, E, F)
Chicago Powdered Metal Products Co. (A, B, C, E, F,)
Cleveland Graphite Bronze Co. (A, B, C, E, F)
Compacted Metals Corp. (B, C)
Dixon Sintaloy, Inc. (B, C, E, F)
Eaton Mfg. Co. (A, B, C, E, F)
Eberhart Steel Products, Powdered Metals Div. (B, C)
Engineered Plastics & American Sinterings, Inc. (B, C, E, F)
Ferro Powdered Metals (B, C, E, F)
General Metal Powder Co. (A, B, C, E, F)
Moraine Products Div., General Motors Corp. (A, B, C, E, F)
General Powdered Metal Products, Inc. (A, B, C, E, F)
General Sintering Corp. (A, B, C, E, F)
Indar Corp. (A, B, C, E, F)
Indiana Steel Products Co. (A, B, C, E, F)
International Powder Metallurgy Co. (A, B, C, E, F)
Jet Components, Inc. (B, C)
Johnson Bronze Co. (A, B, C, E, F)
Keystone Carbon Co. (A, B, C, F)
Kwikset Powdered Metal Products (A, B, C, E, F)
Lux Clock Mfg. Co., Inc. (A, B, C, E, F)
Mallory, P. R. & Co. (A, B, C, E, F)
Merriman Bros. Inc. (A, B, C, E)
Metal Powder Products, Inc. (B, C, F)
Michigan Powdered Metal Products Co. (A, B, C, E, F)
Micro Metallic Corp. (A, B, C, E, F)
Micro-Metals Co. (A, B, C, E, F)
Midwest Sintered Products (A, B, C, E, F)
Mueller Brass Co. (A, B, C, E, F)
National Molded Products, Inc. (A, B, C, E, F)
National Moldite Co. (C)
Pacific Sintered Metals Co. (B, C)
Parker White Metal Co. (A, B, C, E, F)
Picco, Inc. (A, B, C, E, F)
Powder Metal Products Co. (A, B, C, E, F)
Powdercraft Corp. (A, B, C, E, F)
Precision Metal Products Co. (A, B, C, E, F)
Presmet Corp. (A, B, C, E, F)
Pure Carbon Co., Inc. (B)
Raybestos Div., Raybestos-Manhattan, Inc. (A, B, C, E, F)
Reese Metal Products Corp. (A, B, C, E, F)
St. Marys Carbon Co. (A, B, C, E, F, H)
Schwarzkopf Development Corp. (A, B, C, E, F)
Sintercast Corp. of America (A, B, C, E, F)
Sintered Metals, Inc. (B, C, E, F, H)
Sterling Engineering Corp. (B, C)
Superior Carbon Products, Inc. (B, C, E, F)
Supermet Div., Globe Industries, Inc. (B, F)
United Sintered Alloys (A, B, C, E, F)
U.S. Graphite Co. (B, C, E, F)
Veremere, E. A. Inc. (A, B, C, E, F)
Wakefield Bearing Corp. (A, B, C, E, F)
Wellman, S. K. Co. (B, C)
Yale & Towne Mfg. Co., Powdered Metal Products Div. (B, C)

METAL POWDERS (see Iron Powders or specific metal)

METALLIZED COATINGS

(see Coatings)

METHYL METHACRYLATE

(see Acrylic Plastics)

MICA (raw materials and fabricated parts)

Continental-Diamond Fibre Co., Div. of Budd Co.
Farnam Mfg. Co., Inc.
Franklin Mineral Products Co. (12)
Funkhouser Co.
General Electric Co.
Industrial Mica Corp. (13, 23)
Mica Fabricating Co. (10, 13)
Mica Insulator Co., Sub. of Minnesota Mining & Mfg. Co.
Mycalex Corp. of America
U.S. Mica Co., Inc.

MOLDING COMPOUNDS

(see specific plastic or rubber)

MOLDINGS, BLOWN

American Hard Rubber Co. (K)
Belko Corp. (L)
Brown Rubber Co., Inc. (L)
Cadillac Plastic & Chemical Co. (J)

Continental Can Co., Inc. (J)
Dryden Rubber Div., Sheller Mfg. Corp. (L)
Frost Rubber Co. (L)
General Plastics Corp. (J)
Glo-Brite Products, Inc. (K)
Imco Container Corp. (J)
Johnson Rubber Co. (L)
Lee Rubber & Tire Corp. (L)
Luzerne Rubber Co. (L)
Mechanical Rubber Products Co. (K)
Mid-States Rubber Products, Inc. (L)
Naige Co., Inc. (J)
Plax Corp. (J)
Replac Corp. (J, K, L)
Rogers Corp. (L)
Schwab Plastic Corp. (J)
Seamless Rubber Co. (L)
Shoe Form Co. (J)
Stockwell Rubber Co., Inc. (L)
Stokes Molded Products Div., Electric Storage Battery Co. (K)
Sun Rubber Co. (L)
Urrite Plastics Fabricators (J)
Valley-National Corp. (J)
Westlake Plastics Co. (J)

MOLDINGS, COLD

Acushnet Process Co. (L)
American Hard Rubber Co. (J)
American Insulator Corp. (K)
Apex Reinforced Plastics Div., White Sewing Machine Corp. (K)
Biggs, Carl H. Co., Inc. (K)
Dryden Rubber Div., Sheller Mfg. Corp. (L)
Federal Adhesives Corp. (J)
Garfield Mfg. Co. (K)
Glo-Brite Products, Inc. (K)
Home Rubber Co. (L)
Porter, William Co. (K)
Replac Corp. (J, K, L)
Rostone Corp. (K)
Seamless Rubber Co. (L)
Sparta Mfg. Co., Div. of U.S. Ceramic Tile Co. (J)
Square D Co., Molded Insulation Div. (K)

MOLDINGS, COMPRESSION

Acushnet Process Co. (L)
Admiral Corp., Molded Products Div. (K)
Allegheny Plastics, Inc. (J)
Amco Plastic Pipe Co. (K)
American Agile Corp. (J)
American Hard Rubber Co. (J, K, L)
American Molding Co. (K)
American Plastics Corp. (K)
Anderson Associates, Inc. (K)
Apex Reinforced Plastics Div., White Sewing Machine Corp. (K)
Auburn Plastics Inc. (K)
Belko Corp. (L)
Bond International Inc. (L)
Booker-Wallestad, Inc. (K)
Boonton Molding Co. (J)
Burwood Products Co. (J, K)
Button Corp. of America (K)
Capac Industries, Inc. (K)
Chicago Rubber Co., Inc. (L)
Colt's Plastics Co., Inc. (K, L)
Conneaut Rubber and Plastics Co. (J, K, L)
Connecticut Hard Rubber Co. (L)
Consolidated Molded Products Corp. (K)
Continental Rubber Works (L)
Continental-Diamond Fibre Corp., Div. of Budd Co. (K)
Cox Plastics Corp. (K)
Davidson Rubber Co. (L)
Davies, Harry Molding Co. (K)
Diemolding Corp. (K)
Dimco-Gray Co. (K)
Disogrin Industries, Inc. (L)
Dryden Rubber Div., Sheller Mfg. Corp. (L)
Eberhard Faber Pencil Co. (L)
Eby, Hugh H. Co. (K)
Evans-Winter-Hebb, Inc. (K)
Firestone Tire & Rubber Co. (L)
Formold Plastics, Inc. (K)
Frost Rubber Co. (L)
Garfield Mfg. Co. (K)
Geauga Industries Co. (L)
General American Transportation Corp. (K)
General Industries Co., Plastics Div. (K)
Goodrich, B. F. Industrial Products Co. (J)
Goshen Rubber Co., Inc. (L)
Hawkeye Rubber Mfg. Co. (L)
Hays Mfg. Co. (K)
Hewitt-Robins, Inc. (L)
Hohwieler Rubber Co., Inc. (L)
Insulation Products Co. (K)
Johnson Rubber Co. (L)
Judsen Rubber Works, Inc. (L)
Kerr, R. W. Plastic Co. (K)
Koller Craft Plastics Products Inc. (J, K)
Kuhn & Jacob Molding & Tool Co. (K)
Kurz-Kasch, Inc. (J, K)
Lee Rubber & Tire Corp. (L)
Liepsner, H. C. & Co. (K)
Lunn Laminates, Inc. (K)
Luzerne Rubber Co. (J, K, L)
Mechanical Rubber Products Co. (K)
Mesa Plastics Co. (K)
Mid-States Rubber Products, Inc. (L)
Midwest Molding & Mfg. Co. (J, K, L)
Minnesota Rubber & Gasket Co. (J, L)
Moldex (L)
National Gasket & Washer Mfg. Co., Inc. (J, K, L)
Northern Industrial Chemical Co., Inc. (K)
Northwest Plastics, Inc. (K)
Panelyte Div., St. Regis Paper Co. (K)
Parker Appliance Co. (L)
Parker, Stearns & Co., Inc. (L)
Peerless Molded Plastics, Inc. (K)
Plastic & Rubber Products (L)
Plastic Masters, Inc. (K)
Plastic Mold & Tool Co. (J)
Plastic Research Products Co., Div. of Grimes Mfg. Co. (K)
Porter, William Co. (K, L)
Practi-Cole Products, Inc. (J)
Prince Rubber Co., Inc. (J, L)
Quaker Rubber Div., H. K. Porter Co. (K)
Rathbun Molding Corp. (K)
Raybestos-Manhattan, Inc. (K, L)
Regal Plastic Co. (K)
Remler Co. (K)
Replac Corp. (J, K, L)
Resinoid Engineering Corp. (K)
Resistoflex Corp. (J)
Richardson Co. (K)
Robot Devices Inc. (K)
Rogers Corp. (K, L)
Rogers, V. F. Plastic Molding (K, L)
Roth Rubber Co. (K, L)
Russell Reinforced Plastics Corp. (K)
Seamless Rubber Co. (L)
Seaview Plastics, Inc. (K)
Shamban, W. S. & Co. (J)
Shaw Insulator Co. (K)
Sierra Electric Corp. (K, L)
Southern Plastics Co. (K)
Sparta Mfg. Co., Div. of U.S. Ceramic Tile Co. (J)
Square D Co., Molded Insulation Div. (K)
Stalwart Rubber Co. (L)
Standard Products Co. (L)
Stockwell Rubber Co., Inc. (J, L)
Stokes Molded Products, Div. of Electric Storage Battery Co. (K)
Sun Rubber Co. (L)
Sylvania Electric Products Inc. (K)
Synthane Corp. (K)
Teal Co. (K)
Technical Specialties Co. (L)
Toledo Industrial Rubber Co. (K)
U.S. Rubber Co., Mechanical Goods Div. (K)
U.S. Stoneware Co. (J, K)
Vogt Mfg. Corp. (J)
Vulcanized Rubber & Plastics Co. (L)
Waterbury Companies, Inc. (J, K)
Westlake Plastics Co. (K)
Westmoreland Plastics Co., Inc. (K)
Wittman, Lawrence & Co. (K)
Zenith Plastics Co. (K)

MOLDINGS, INJECTION

aaRBee Plastic Co. (J)
AGP Corp. (J)
Acushnet Process Co. (L)
Admiral Corp., Molded Products Div. (J)
All Plastics Corp. (J)
Amco Plastic Pipe Co. (J)
American Agile Corp. (J)
American Hard Rubber Co. (J, L)
American Insulator Corp. (J, L)
American Molding Co. (J)
American Plastics Corp. (J)
Amos Molded Plastics Div., Amos-Thompson Corp. (J, K)
Anderson Associates, Inc. (J)
Auburn Plastics Inc. (J, L)
Auburn Rubber Co., Inc. (J)
Belko Corp. (L)
Bond International Inc. (L)
Booker-Wallestad, Inc. (J)
Boonton Molding Co. (J)
Buckeye Molding Co. (J)
Burwood Products Co. (J)
Campro Co. (J)
Chippewa Plastics, Inc. (J)
Colonial Art Co., Inc. (J)
Colonial Plastics Mfg. Co. (J)
Colt's Plastics Co., Inc. (J)
Commercial Plastics Co., Associated Plastic Div. (J)
Conneaut Rubber and Plastics Co. (J, K, L)
Consolidated Molded Products Corp. (J)
Continental Can Co., Inc. (J)
Continental Rubber Works (L)
Continental-Diamond Fibre Corp., Div. of Budd Co. (J)
Dapol Plastics, Inc. (J)
Dryden Rubber Div., Sheller Mfg. Corp. (L)
Eby, Hugh H. Co. (J)
Engineered Nylon Products, Inc. (J)
Evans-Winter-Hebb, Inc. (J, K)
Fiberfil, Inc. (J)
Formold Plastics, Inc. (J)
Franklin Plastics, Inc. (J)
Geauga Industries Co. (L)
General American Transportation Corp. (J)
General Industries Co., Plastics Div. (J)
Glass Laboratories Inc. (J)
Gotham Plastics Corp. (J)
Gries Reproducer Corp. (J)
H & R Industries (J)
Harback Mfg. Co. (J)
Hawkeye Rubber Mfg. Co. (L)
Hungerford Plastics Corp. (L)
Ideal Plastics Co. (J)
Imco Container Corp. (J)
Johnson Glass & Plastic Corp. (J)
Johnson Plastic Corp. (J, L)
Judsen Rubber Works, Inc. (L)
Keolyn Plastics, Inc. (J)
Kerr, R. W. Plastic Co. (J, L)
Koller Craft Plastics Products Inc. (J)
Lermer Plastics, Inc. (J)
Liepsner, H. C. & Co. (J)
Luzerne Rubber Co. (J)
Manufacturers Corp. (J)
Mechanical Rubber Products Co. (K)
Midwest Molding & Mfg. Co. (J, K, L)
Minnesota Rubber & Gasket Co. (L)
Moldex (L)
Naige Co., Inc. (J)
Niles Corp. (J)
Northern Industrial Chemical Co., Inc. (J)
Northwest Plastics, Inc. (J, L)
Ohio Rubber Co. (J)
Panelyte Div., St. Regis Paper Co. (J)
Peerless Molded Plastics, Inc. (J)
Plastic Masters Inc. (J)

Plax Corp. (J)
Plura Plastics (J)
Porter, William Co. (J)
Practi-Cole Products, Inc. (K)
Prince Rubber Co., Inc. (J, L)
Pyro Plastics Corp. (J)
Rathbun Molding Corp. (J)
Raybestos-Manhattan, Inc. (L)
Remler Co. (J)
Richardson Co. (J)
Rogers, Dayton Mfg. Co. (J)
Shamban, W. S. & Co. (J)
Shaw Insulator Co. (J)
Sierra Electric Corp. (J, L)
Sinko Mfg. & Tool Co. (J)
Skyline Industries (J)
Standard Molding Corp. (J)
Standard Products Co. (L)
Stockwell Rubber Co., Inc. (L)
Stokes Molded Products, Div. of Electric Storage Battery Co. (J)
Sylvania Electric Products Inc. (J)
Teal Co. (J)
Technical Specialties Co. (L)
Toledo Industrial Rubber Co. (K)
Trim Molded Products Co., Inc. (J)
Tube Turns Plastics, Inc. (J)
United Plastic Industries, Inc. (J)
U.S. Rubber Co., Mechanical Goods Div. (J)
Vulcanized Rubber & Plastics Co. (J, L)
Wagner Plastic Corp. (J)
Waterbury Companies, Inc. (J)
Westlake Plastics Co. (J)
Whyte Mfg. Co., Inc. (J)
Zenith Plastics Co. (J)

MOLDINGS, SHEET
(sheet formed parts)

American Agile Corp. (J)
American Plastics Corp. (J)
Artmor Plastics Corp. (K)
Auburn Mfg. Co. (J)
Belko Corp. (L)
Blank, Arthur & Co., Inc. (J)
Brown Rubber Co., Inc. (L)
Cadillac Plastic & Chemical Co. (J)
Capac Industries, Inc. (J)
Carroll, J. B. Co. (J)
Connecticut Hard Rubber Co. (L)
Dryden Rubber Div., Sheller Mfg. Corp (L)
Dura Plastics of New York, Inc. (J)
Eljay Corp. (J)
General American Transportation Corp. (J)
General Plastics Corp. (J)
General Plastics Mfg. Co. (J, K)
General Tire & Rubber Co. (K)
Gotham Plastics Corp. (J)
Imco Container Corp. (J)
Kerr, R. W. Plastic Co. (J)
Klise Mfg. Co., Inc. (J)
Lunn Laminates, Inc. (J, K)
Masland Duraleather Co. (J)
Mechanical Rubber Products Co. (K)
Mica Insulator Co. (K)
Midwest Plastic Products Co. (J)
Minnesota Mining & Mfg. Co. (K)
Nalge Co., Inc. (J)
O'Sullivan Rubber Corp. (J)
Panelyte Div., St. Regis Paper Co. (J)
Peerless Products Industries (J)
Porter, William Co. (K)
Practi-Cole Products, Inc. (J)
Regal Plastics Co. (J)
Replac Corp. (J, K, L)
Resolite Corp. (K)
Seamless Rubber Co. (L)
Seaview Plastics, Inc. (J)
Sewell Mfg. Co. (J)
Shamban, W. S. & Co. (J)
Shoe Form Co. (J)
Sierra Electric Corp. (J)
Sillcocks Miller Co. (J)
Snyder Mfg. Co., Inc. (J)
Sparta Mfg. Co., Div. of U.S. Ceramic Tile Co. (J)
Strick Plastic Co. (J, L)
Trim Molded Products Co., Inc. (J)
U.S. Rubber Co. (J)
Urrite Plastics Fabricators (J)
Valley-National Corp. (J)
Vogt Mfg. Corp. (J)
Westlake Plastics Co. (J)
Whyte Mfg. Co., Inc. (J)
Wittman, Lawrence & Co. (K)

MOLDINGS, SLUSH (Plastics)

Boonton Molding Co. (L)
Borden Co., Chemical Div. (J)
Chemical Products Corp. (J)
Dennis Chemical Co. (J)
Dryden Rubber Div., Sheller Mfg. Corp. (L)
Federal Adhesives Corp. (J)
Hungerford Plastics Corp. (J)
Minnesota Rubber & Gasket Co. (J, L)
Replac Corp. (J, K, L)

MOLDINGS, TRANSFER

Acushnet Process Co. (L)
Admiral Corp. (K)
Amco Plastic Pipe Co. (K)
American Hard Rubber Co. (J, K, L)
American Insulator Corp. (K)
American Molding Co. (K)
American Plastics Corp. (K)
Belko Corp. (L)
Bond International Inc. (L)
Booker-Wallestad, Inc. (K)
Boonton Molding Co. (J)
Colt's Plastics Co., Inc. (K)
Continental Rubber Works (L)
Cox Plastics Corp. (K)
Davies, Harry Molding Co. (K)
Dimco-Gray Co. (K)
Disogrin Industries, Inc. (L)
Dryden Rubber Div., Sheller Mfg. Corp. (L)
Eby, Hugh H. Co. (K)
Evans-Winter-Hebb, Inc. (K)
Formica Corp. (J)
Formold Plastics, Inc. (K)
Garfield Mfg. Co. (K)
General American Transportation Corp. (K)
General Industries Co., Plastics Div. (K)
Hawkeye Rubber Mfg. Co. (L)
Insulation Products Co. (K)
Johnson Rubber Co. (L)
Judsen Rubber Works, Inc. (L)
Kerr, R. W. Plastic Co. (K)
Koller Craft Plastics Products Inc. (K)
Kurz-Kasch, Inc. (J, K)
Lee Rubber & Tire Corp. (L)
Mechanical Rubber Products Co. (K)
Mesa Plastics Co. (K)
Mid-States Rubber Products, Inc. (L)
Midwest Molding & Mfg. Co. (J, K, L)
Minnesota Rubber & Gasket Co. (L)
Moldex (L)
Northern Industrial Chemical Co., Inc. (K)
Northwest Plastics, Inc. (K)
Panelyte Div., St. Regis Paper Co. (K)
Parker Appliance Co. (L)
Peerless Molded Plastics, Inc. (K)
Plastic Masters, Inc. (K)
Plastic Research Products Co., Div. of Grimes Mfg. Co. (K)
Rathbun Molding Corp. (K)
Raybestos-Manhattan, Inc. (L)
Remler Co. (K)
Replac Corp. (J, K, L)
Resinoid Engineering Corp. (K)
Richardson Co. (K)
Robot Devices Inc. (K)
Rogers Corp. (K)
Roth Rubber Co. (L)
Seamless Rubber Co. (L)
Shaw Insulator Co. (K)
Sierra Electric Corp. (K)
Southern Plastics Co. (K)
Square D Co., Molded Insulation Div. (K)
Standard Products Co. (L)
Stockwell Rubber Co., Inc. (L)
Stokes Molded Products, Div. of Electric Storage Battery Co. (K)
Sun Rubber Co. (L)
Sylvania Electric Products Inc. (K)
Teal Co. (K)
Technical Specialties Co. (L)
Toledo Industrial Rubber Co. (K)
U.S. Rubber Co., Mechanical Goods Div. (K)
Vulcanized Rubber & Plastics Co. (L)
Waterbury Companies, Inc. (K)

MOLYBDENUM AND ITS ALLOYS

Alpha Metals, Inc. (13, 14)
Amalgamated Steel Corp. (2, 12)
Associated Engineering & Mfg. Corp. (2, 10, 12, 13, 14)
Belmont Smelting & Refining Works, Inc. (8, 10)
Cleveland Tungsten, Inc. (10)
Climax Molybdenum Co. (2, 3, 8, 9, 12, 13, 14)
Electro Metallurgical Co., Div. of Union Carbide Corp. (10)
Fansteel Metallurgical Corp. (2, 8, 9, 10, 12, 13, 14)
General Electric Co., Lamp Wire & Phosphors Dept. (10)
Hardy, Charles Inc. (10)
North American Phillips Co., Inc. (10)
Shieldalloy Corp. (10)
Sylvania Electric Products Inc. (2, 8, 10)
Vacuum Metals Corp., Div. of Crucible Steel Co. of America (2, 3, 8, 9, 13, 14)
Westinghouse Electric Corp., Lamp Div.

MONEL (see Nickel)

NATURAL RUBBER

American Hard Rubber Co. (12, 13, 14)
American Rubber Products Corp. (21, 13, 14, 12)
Atlas Mineral Products Co. (13)
Auburn Rubber Co., Inc. (13)
Brown Rubber Co., Inc. (21)
Continental Rubber Works (22, 12, 13, 14)
Coyne & Paddock Inc. (13)
Foamade Industries (21)
Geauga Industries Co. (22, 12, 14)
Goshen Rubber Co., Inc. (22)
Home Rubber Co. (22, 12, 13, 14)
Johns-Manville Corp. (13)
Luzerne Rubber Co. (12, 13, 14)
Mid-States Rubber Products, Inc. (22, 13, 14)
Parker, Stearns & Co., Inc. (13, 14, 20)
Polymer Chemical Co. (22)
Rand Rubber Co. (17, 20, 13)
Raybestos-Manhattan, Inc. (12, 13, 14)
Rogers Corp. (12, 13, 14, 22)
Roth Rubber Co. (22, 13)
Rubatex Div., Great American Industries, Inc. (21)
Rubber Corp. of America (17, 21)
Standard Products Co. (22)
Stockwell Rubber Co., Inc. (21, 22, 12, 13, 14)
Technical Specialties Co. (14)
U.S. Stoneware Co. (22)
Vulcanized Rubber & Plastics Co. (22)

Bold face indicates supplier advertises product in this issue

NEOPRENE (see Chloroprene Rubber)

NICKEL AND ITS ALLOYS

Alloy Metal Powders, Inc. (10)
Alloy Metal Products, Inc. (3, 8)
Amalgamated Steel Corp. (2, 12)
American Nickel Alloy Mfg. Corp. (8)
American Silver Co., Inc. (7, 14)
Belmont Smelting & Refining Works, Inc. (1, 8, 10)
Brush Beryllium Co. (8)
Driver, Wilbur B. Co. (12, 14)
Driver-Harris Co. (7, 12, 14)
Elgin National Watch Co. (3, 12, 14)
Federated Metals Div., American Smelting & Refining Co. (8)
Firth Sterling Inc. (2, 3, 8, 12, 14)
Foote Mineral Co. (10)
Fox Products Co. (1)
General Plate Div., Metals & Controls Corp. (7, 13, 14)
Grand Rapids Brass Co. (9)
Hardy, Charles, Inc. (10)
Hayden Wire Works, Inc. (12)
Haynes Stellite Co., Div. of Union Carbide Corp. (2, 9, 12, 13, 14)
Hoskins Mfg. Co.
International Nickel Co., Inc. (2, 9, 12, 13, 14)
Lavin, R. & Sons, Inc. (8)
McGean Chemical Co. (1)
Metal Hydrides Inc. (8, 10)
Metals Disintegrating Co., Inc. (10)
New England Brass Co. (13, 14)
New Jersey Metals Co. (1, 3, 8)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (7, 8)
Plastic Metals Div., National-U.S. Radiator Corp. (10)
Riverside Alloy Metal Div., H. K. Porter Co., Inc. (2, 12, 13, 14)
Sel-Rex Corp. (1, 10)
Seymour Mfg. Co. (1, 12, 13, 14)
Shieldalloy Corp. (10)
Somers Brass Co., Inc. (14)
Superior Steel Corp. (14)
Utica Drop Forge & Tool Div., Kelsey Hayes Co. (2, 3, 8, 9, 13, 14)
Utility Mfg. Co. (12)
Vanadium-Alloys Steel Co. (10)
Wall Colmonoy Corp. (10, 12)
Waterbury Rolling Mills, Inc. (14)
Whitehead Metal Products Co., Inc. (9, 12, 13, 14)
Wilson, H. A. Co. (12, 14)

NICKEL SILVER (see Copper)

NITRIDES (see Ceramics)

NITRILE RUBBER
(see Acrylonitrile-Butadiene Rubber)

NODULAR IRON (see Iron)

NYLON (see Polyamides)

OXIDES (see Ceramics)

PAPERS, INDUSTRIAL
(cellulose, inorganic, synthetic)

Dexter, C. H. & Sons Inc.
Filpaco Industries, Inc.
Fox Edge Co., Inc.
Georgia-Pacific Corp.
Gomar Mfg. Co., Inc.
Hollingsworth & Vose Co.
Johns-Manville Corp.
Knowlton Bros., Inc.
Mica Fabricating Co.
Mosinee Paper Mills Co.
Owens-Illinois Glass Co.
Raybestos-Manhattan, Inc.
Riegel Paper Corp.
Rogers Corp.
St. Regis Paper Co.
Spruce Pine Mica Co., Inc.
Standard Asbestos Mfg. Co.
Standard Washer & Mat Inc.

PERFORATED METALS

Acme Precision Products, Inc. (A, B, F, G)
American Sheet Metal Works, Inc. (F)
Blaco Mfg. Co. (B, F)
California Perforated Screen Co. (A, B, C, E, F, H)
Caspers Tin Plate Co. (F)
Chase Brass & Copper Co. (B)
Clendenin Bros. Inc. (A, B)
Colonial Alloys Co. (A, B, D, E, F, G, H)
Colorado Fuel and Iron Corp. (F)
Cross Engineering Co. (A, F)
Duplex Mfg. Corp. (F)
Etched Products Corp. (A)
Falstrom Co. (A, B, D, F)
Fox Products Co. (C)
General Alloys Co. (A, B, E, F)
Greene, G. G. Corp. (F)
Harrington & King Perforating Co., Inc. (A, B, C, D, E, F, G, H)
Haven-Busch Co. (A, B, F)
Hawkridge Bros. Co. (A)
Hendrick Mfg. Co. (A, B, C, D, E, F, G, H)
Houston Blow Pipe & Sheet Metal Works (A, B, F)
Industrial and Furnace Car Div., Irwin Foundry and Mine Car Co. (F)
Levinson Steel Co. (F)
McCarter Iron Works Inc. (F)
McNally Pittsburg Mfg. Co. (A, F)
Melco Wire Products (A)
Metal Goods Corp. (A, B, E, F)
Parker Metal Goods Co. (A, F)
Reynolds Metals Co. (A)
Rigidized Metals Corp. (A, B, F, G)
Ryerson, Joseph T. & Son, Inc. (A, F)
Servwell Products Co. (B, F)
Stainless Metals, Inc. (F)
Standard Stamping & Perforating Co. (A, B, F)
Thompson Pipe & Steel Co. (F)
Toepfer & Sons, Inc. (A, B, C, D, E, F, G, H)
Whitehead Metal Products Co., Inc. (A, B, E)
Whyte, Oliver Co., Inc. (A, F)

PERMANENT MOLD CASTINGS
(see Castings)

PHENOLICS

Ace Plastic Co. (12, 13, 14)
Adhesive Products Corp. (18)
American Reinforced Plastics Co. (22, 17)
Archer-Daniels-Midland Co. (17)
Auburn Plastic Engineering (12, 13)
Bakelite Co., Div. of Union Carbide Corp. (17, 18, 21, 22)
Barrett Div., Allied Chemical & Dye Corp. (17)
Bisonite Co., Inc. (18)
Borden Co., Chemical Div. (17, 18)
Cadillac Plastic & Chemical Co. (12, 13, 14)
Capac Industries, Inc. (13, 14)
Catalin Corp. of America (17)
Chemical Process Co. (17)
Coast Mfg. & Supply Co. (22)
Commercial Plastics & Supply Corp. (12, 13, 14)
Consoweld Corp. (13)
Douglas & Sturgess (18)
Dunnican Associates (22, 17)
Durez Plastics Div., Hooker Electrochemical Corp. (17, 18, 22)
Falge Engineering Corp. (20)
Farley & Loetscher Mfg. Co., Plastics Div. (13)
Fiberite Corp. (22)
Formica Corp. (12, 13, 14)
General Electric Co. (22, 17)
Haskelite Mfg. Corp. (13, 14)
Iten Fibre Co. (13, 14)
Lewis, J. P. Co., Plastic Products Div. (13)
Loven Chemical Co. of California (22, 17)
Marblette Corp. (17, 18, 21, 12, 13)
Mica Insulator Co. (12, 13)
Minnesota Mining & Mfg. Co. (19)
Monsanto Chemical Co. (22, 17)
Muehlstein, H. & Co., Inc. (22, 17)
National Vulcanized Fibre Co. (12, 13)
New England Laminates Co., Inc. (13)
Northern Plastics Corp. (13, 14)
Omni Products Corp. (22)
Philrus Products Co. (12, 13, 14)
Plastics Engineering Co. (22, 17)
Pyrosil, Inc. (18, 12)
Reichhold Chemicals, Inc. (17, 18)
Reilly Tar & Chemical Corp. (22, 17)
Rezolin, Inc. (18, 21)
Rogers Corp. (22, 13, 14)
Schenectady Varnish Co., Inc. (17, 18)
Spaulding Fibre Co., Inc. (12, 13, 14)
Strick Plastics Co. (21, 13)
Synco Resins, Inc. (17, 18)
Synthane Corp. (12, 13, 14)
Taylor Fibre Co. (12, 13)
Texas Glass Fiber Corp. (22)
Thombert, Inc. (12, 13, 14)
Varcum Chemical Corp. (17)
Watertown Mfg. Co. (22, 17)
Westlake Plastics Co. (12, 13, 14)
Wilmington Fibre Specialty Co. (12, 13)

PHOSPHOR BRONZE (see Copper)

PIPE (see Tubing)

PLASTER MOLD CASTINGS
(see Castings)

PLASTICS
(see specific material and form)

PLATE (see specific metal)

PLATINUM AND PLATINUM GROUP ALLOYS

American Metal Co. Ltd. (10)
American Platinum Works
American Silver Co., Inc. (7, 14)
Baker & Co., Inc. (1, 2, 7, 8, 9, 10, 12, 13, 14)
Bishop, J. & Co.
Eastern Smelting & Refining Corp. (10)
General Plate Div., Metals & Controls Corp. (1, 7, 9, 12, 13, 14)
Goldsmith Bros., S. & R. Co. (2, 7, 8, 9, 12, 13, 14)
Hagstoz, R. B. & Son (12, 13, 1, 2, 9)
Handy & Harman (1, 2, 9, 10, 12, 13, 14)
Hanovia Chemical & Mfg. Co. (10)
Hardy, Charles Inc. (10)
Leach & Garner Co., Industrial Div. (12, 13, 14)
Ney, J. M. Co.

Sel-Rex Corp. (1, 10)
Western Gold & Platinum Co. (1, 12, 14)
Wildberg Bros. Smelting & Refining Co. (1, 2, 3, 7, 8, 9, 10, 12, 13, 14)
Williams Gold Refining Co., Inc. (1, 2, 3, 7, 8, 9, 10, 12, 14)

POLYAMIDES

Ace Plastics Co. (12, 14)
American Hard Rubber Co. (12)
American Molding Powder & Chemical Corp. (22)
Anchor Plastics Co., Inc. (12, 14)
Auburn Plastic Engineering (12, 13, 14)
Bamberger, Claude P. Inc. (22)
Barrett Div., Allied Chemical & Dye Corp. (22)
Belding Corticelli Industries (17, 18, 22)
Catalin Corp. of America (22)
Commercial Plastics & Supply Corp. (12, 13, 14)
du Pont de Nemours, E. I. & Co., Inc. (17, 19, 22)
Fiberfil, Inc. (19, 22)
Fox Edge Co., Inc. (19)
Fry Plastics Co. (12, 13)
General Mills, Inc., Chemical Div. (17, 18)
Glass Laboratories Inc. (12, 14)
H & R Industries (20, 12, 13, 14, 18)
Muehlstein, H & Co., Inc. (22)
National Vulcanized Fibre Co. (12)
Polymer Corp. (20, 12, 13, 14, 22)
Reichhold Chemicals, Inc. (17)
Southern Plastics Co. (12, 13, 14)
Spencer Chemical Co. (17)
Thombert, Inc. (12, 13, 14)
U.S. Gasket Co., Div. of Garlock Packing Co. (2, 9, 12)
Westlake Plastics Co. (12, 13, 14)

POLYCARBONATE PLASTICS

General Electric Co. (17)

POLYESTERS

Adhesive Products Corp. (18)
Alsynite Co. of America (13)
American Cyanamid Co, Plastics & Resins Div. (17, 18)
American Hard Rubber Co. (13)
American Products Mfg. Co., Inc. (17)
Archer-Daniels-Midland Co. (17)
Atlas Powder Co. (18, 22)
Auburn Plastic Engineering (12, 13)
Bakelite Co., Div. of Union Carbide Corp. (17, 18)
Barrett Div., Allied Chemical & Dye Corp. (17, 21)
Boonton Molding Co. (18)
Booty Resineers, Inc. (17)
Brown Rubber Co., Inc. (21)
Cadillac Plastic & Chemical Co. (18, 12, 13, 14)
Cast Optics Corp. (13)
Celanese Corp. of America (17, 18)
Chemical Process Co. (17)
Coating Products (20)
Cordo Molding Products, Inc. (17)
Corrulux Div., L.O.F. Glass Fibers Co. (13)
Douglas & Sturgess (18)
du Pont de Nemours, E. I. & Co., Inc. (19)
Durez Plastics Div., Hooker Electrochemical Corp. (17, 18, 22)
Everlite Corp. (13)
Falge Engineering Corp. (20)
Foamade Industries (21)
Foss Mfg. Co., Plastics Div. (18)
Fry Plastics Co. (17)
General Electric Co. (18)
Glastic Corp. (12, 13, 14)
Glidden Co. (17)
Haskelite Mfg. Corp. (13, 14)
Hays Mfg. Co. (22, 13)
Interchemical Corp. (17, 18, 21, 22)
Loven Chemical Co. of California (17)
Luminous Resins, Inc. (22)
Minnesota Mining & Mfg. Co. (19)
Mobay Chemical Co. (17)
Muehlstein, H. & Co., Inc. (17)
National Vulcanized Fibre Co. (13)
Naugatuck Chemical Div., U.S. Rubber Co. (17)
Omni Products Corp. (17)
Philrus Products Co. (12, 13, 14)
Pittsburgh Plate Glass Co. (17)
Reichhold Chemicals, Inc. (17, 18, 21)
Robertson, H. H. Co. (17)
Rohm & Haas Co. (17, 18)
Schwartz Chemical Co., Inc. (18)
Specialty Resins Co. (17)
Strick Plastics Co. (21, 13, 14)
Texas Plastic Development Corp. (17)
Thalco (17)
Thermaflow Chemical Corp. (17)
Thiokol Chemical Corp. (17)

POLYETHYLENES

Ace Plastic Co. (12, 13, 14)
Adhesive Products Corp. (18)
Aladdin Products Co. (13)
American Agile Corp. (18, 20, 21, 12, 13, 14)
American Hard Rubber Co. (12, 14)
American Molding Powder & Chemical Co. (22)
American Rattan & Reed Mfg. Co. (19)
Anchor Plastics Co., Inc. (12, 14)
Auburn Plastic Engineering (20, 12, 13)
Bakelite Co., Div. of Union Carbide Corp. (17, 21, 22)
Bamberger, Claude P. Inc. (22)
Blossom Mfg. Co. Inc. (20, 13, 14)
Cadillac Plastic & Chemical Co. (20, 12, 13, 14)
Campco Div., Chicago Molded Products Corp. (20, 13)
Catalin Corp. of America (22)
Celanese Corp. of America (17, 22)
Chester Packaging Products Corp. (20, 13)
Chippewa Plastics, Inc. (20, 13)
Clopay Corp. (20, 13)
Conneaut Rubber & Plastics Co. (18, 20, 22, 12, 13, 14)
Contour Extrusion Co. (12, 13, 14)
Coyne & Paddock, Inc. (22)
Crystal Corp. (13, 20)
Dow Chemical Co. (22)
du Pont de Nemours, E. I. & Co., Inc. (17, 22)
Durethene Corp. (20)
Eastman Chemical Products, Inc. (22)
Extruders, Inc. (13, 20)
Falge Engineering Corp. (20)
Fiberfil, Inc. (19, 22)
Firestone Plastics Co. (13, 20)
Fry Plastics Co. (13, 20)
Fullerton Mfg. Co. (22)
Geauga Industries Co. (12, 14)
General Electric Co. (20)
General Tire & Rubber Co. (13, 20)
Genesee Lab, Inc. (17)
Gering Products, Inc. (20, 22, 12, 13, 14)
Glass Laboratories (12, 14)
Goodrich-Gulf Chemicals, Inc. (17)
Grace, W. R. & Co., Polymer Chemicals Div. (17)
H & R Industries (20, 12, 13, 14)
Harte & Co., Inc. (13, 20)
Hercules Powder Co. (17, 22)
Hydrawlik Co. (12, 14)
Industrial Plastics Corp. (12, 14)
Jet Specialties Co., Inc. (13, 20)
KSH Plastics, Inc. (12, 13, 14)
Kaykor Industries, Inc. (13)
Koppers Co., Inc., Chemical Div. (17, 22)
Kuss, R. L. & Co., Inc. (20)
Luminous Resins, Inc. (22)
Mason Envelope Co., Inc. (20)
Midwest Plastic Products Co., (13, 14)
Molded Fiber Glass Sheet Co. (13)
Monsanto Chemical Co., Plastics Div. (17, 18, 22)
Muehlstein, H. & Co., Inc. (22)
Nalge Co., Inc. (12, 13, 14)
New England Tape Co., Inc. (14)
Omni Products Corp. (22)
Pacific Coast Foil Co. (20)
Perfex Plastics, Inc. (12, 14)
Phillips Chemical Co., Div. of Phillips Petroleum Co. (22)
Plastic Packaging Co. (20)
Plax Corp. (20, 13)
Polo Plastics Co. (20)
Poly Plastic Products, Inc. (20, 13)
Presto Plastic Products Co., Inc. (13, 20)
Pyramid Plastics, Inc. (12, 14)
Reed Plastics Corp. (22)
Reliance Plastic & Chemical Corp. (20, 12, 14)
Reynolds Metals Co. (13, 20)
Schwab Plastics Corp. (21, 12, 14)
Seiberling Rubber Co., Plastics Div. (13)
Shellmar-Betner Flexible Packaging Div., Continental Can Co., Inc. (13, 20)
Simon Products Co. (20)
Snyder Mfg. Co., Inc. (20, 13)
Southern Plastics Co. (20, 12, 13, 14)
Spencer Chemical Co. (17)
Supplex Co., Div. of American Hard Rubber Co. (22, 12, 14)
U.S. Industrial Chemicals Div., National Distillers & Chemical Corp. (17, 22)
U.S. Stoneware Co. (22)

KEY

MATERIALS

A—Aluminum and its alloys
B—Copper and its alloys
C—Iron and its alloys (except steel)
D—Magnesium and its alloys
E—Nickel and its alloys
F—Steels
G—Titanium and its alloys
H—Zinc and its alloys
J—Thermoplastics
K—Thermosetting plastics
L—Elastomers

BASIC FORMS

1—Anodes
2—Bar
3—Billets
7—Foil
8—Ingot
9—Plate
10—Powder
12—Rod
13—Sheet
14—Strip
17—Base resins, polymers or gums
18—Laminating or casting resins
19—Fibers or filaments
20—Film
21—Foams (component materials or products)
22—Molding compounds
23—Tube, nonmetallic (except plastics or rubber)

Visking Corp., Plastics Div. (13, 20)
Vogt Mfg. Corp. (12, 14)
Westlake Plastics Co. (12, 13, 14, 20)
World Plastex (12, 13, 14)

POLYSTYRENES
(incl copolymers and modifications)

Adhesive Products Corp. (18)
Ambassador Plastics & Mfg. Corp. (21)
American Cyanamid Co., Plastics & Resins Div. (22)
American Hard Rubber Co. (12, 13, 14)
American Molding Powder & Chemical Co. (22)
Anchor Plastics Co., Inc. (12, 14)
Auburn Plastic Engineering (12, 13)
Bakelite Co., Div. of Union Carbide Corp. (17, 22)
Bamberger, Claude P. Inc. (22)
Cadillac Plastic & Chemical Co. (20, 12, 13, 14)
Campco Div., Chicago Molded Products Corp. (20, 13)
Capac Industries, Inc. (13, 14)
Catalin Corp. of America (22)
Chemical Process Co. (17)
Chippewa Plastics, Inc. (12)
Coating Products (20)
Colonial Art Co., Inc. (13)
Commercial Plastics & Supply Corp. (12, 13, 14)
Conneaut Rubber & Plastics Co. (22, 13, 14, 12)
Dewey & Almy Chemical Co., Div. of W. R. Grace Co. (17)
Dow Chemical Co. (17, 21, 22)
Dura Plastics of New York, Inc. (12, 13)
Fiberfil, Inc. (19, 22)
Firestone Plastics Co. (17)
Gering Products, Inc. (22, 12, 14)
Glass Laboratories Inc. (12, 14)
Glo-Brite Products, Inc. (21)
Goodyear Tire & Rubber Co. (22)
Grant, Foster Co., Inc. (17, 22)
H & R Industries (12, 13, 14)
Haskelite Mfg. Corp. (21)
Industrial Plastics Corp. (12, 14)
KSH Plastics, Inc. (12, 13, 14)
Kaykor Industries, Inc. (13)
Koppers Co., Inc., Chemical Div. (17, 21, 22)
Luminous Resins, Inc. (22)
Marbon Chemical Div., Borg-Warner Corp. (17, 22)
Monsanto Chemical Co. (17, 22)
Muehlstein, H. & Co. (17, 22)
Nesbit Industries, Inc. (21)
Nixon Nitration Works (12, 13)
Northwest Plastics Industries, Inc. (21)
Omni Products Corp. (22)
O'Sullivan Rubber Corp. (13)
Perfex Plastics, Inc. (12, 14)
Plax Corp. (20, 13)
Polymer Corp. (12, 13)
Pyramid Plastics, Inc. (12, 14)
Reed Plastics Corp. (22)
Schwab Plastics Corp. (21, 12, 14)
Selberling Rubber Co., Plastics Div. (13)
Snyder Mfg. Co., Inc. (20, 13)
Southern Plastics Co. (20, 12, 13, 14)
Strick Plastics Co. (21)
Walsen Consolidated Mercantile Co. (22)
Westlake Plastics Co. (12, 13, 14, 20)
World Plastex (12, 13, 14)

POLYSULFIDE RUBBER

Adhesive Products Corp. (18)
American Hard Rubber Co. (12, 13, 14)
Armstrong Cork Co. (12, 13, 14)
Boruski, Ernest F., Jr. (17)
Home Rubber Co. (22, 12, 13, 14)
Parker, Stearns & Co., Inc. (13, 14)
Thiokol Chemical Corp. (17)
Vulcanized Rubber & Plastics Co. (22)

POLYVINYL ALCOHOLS (see Vinyls)

POLYVINYL CHLORIDE AND COPOLYMERS (see Vinyls)

PORCELAIN (see Ceramics)

PRECOATED METALS—ALUMINIZED

American Chain & Cable Co., Inc. (F)
Armco Steel Corp. (C, F)
Brasco Mfg. Co. (F)
Clad-Rex Corp. (F)
Enamel Products Co. (F)
Jackson Steel Products, Inc. (F)
Mayville Metal Products Co. (F)
Tickle, Arthur Engineering Works, Inc. (C, F, G)
U.S. Steel Corp. (F)
Whitehead Metal Products Co., Inc. (F)
Whyte, Oliver Co., Inc. (F)

PRECOATED METALS—GALVANIZED

Albert Pipe Supply Co., Inc. (F)
American Sheet Metal Works, Inc. (F)
Anderson-Bolling Mfg. Co. (F)
Appalachian Steel Corp. (F)
Armco Steel Corp. (C, F)
Associated Spring Corp. (F)
Bethlehem Steel Co. (F)
Brasco Mfg. Co. (F)
Brewer-Titchener Corp. (F)
Clad-Rex Corp. (F)
Conner Mfg. Co. (F)
Continental Nu-Steel Metal Products Co. (F)
Continental Steel Works Corp. (F)
Enterprise Galvanizing Co. (F)
Grand Sheet Metal Products Co., Consumer Products Div. (C)
Granite City Steel Co. (F)
Hobbs, Clinton E. Co. (C, F)
Houston Blow Pipe & Sheet Metal Works (F)
Ideal Can Co. (F)
Inland Steel Co. (F)
Jackson Steel Products, Inc. (F)
Jones & Laughlin Steel Corp. (F)
Kroh Wagner (F)
Mahon, R. C. Co. (F)
Mayville Metal Products Co. (F)
McNally Pittsburg Mfg. Co. (F)
Metal Goods Corp. (F)
New York Iron Roofing & Corrugating Co., Inc. (F)
Newport Steel Co. (F)
Nikoh Tube Co. (F)
Republic Steel Corp. (F)
Riverside Foundry & Galvanizing Co. (C, F)
Ryerson, Joseph T. & Son, Inc. (F)
Sharon Steel Corp. (F)
Southern Galvanizing Co. (F)
Stenman, Bror F. (F)
Thomas Strip Div., Pittsburgh Steel Co. (F)
U.S. Steel Corp. (F)
Vulcan Rail & Construction Co. (F)
Weirton Steel Co. (F)
Wheeling Steel Corp. (F)
Youngstown Sheet & Tube Co. (F)

PRECOATED METALS—LEAD OR TERNE COATED

American Brass Co. (B)
American Sheet Metal Works, Inc. (F)
Anderson-Bolling Mfg. Co. (F)
Appalachian Steel Corp. (F)
Armco Steel Corp. (C, F)
Avon Tube Div., Higbie Mfg. Co. (F)
Brasco Mfg. Co. (F)
Bridgeport Brass Co. (B)
Cartwright, R. Tube Products Co. (F)
Caspers Tin Plate Co. (F)
Chase Brass & Copper Co. (B)
Follansbee Steel Corp. (F)
Houston Blow Pipe & Sheet Metal Works (F)
Hussey, C. G. Co. (B)
Ideal Can Co. (F)
Metal Goods Corp. (B)
New Haven Copper Co. (B)
Nikoh Tube Co. (F)
Philadelphia Steel & Wire Corp. (F)
Republic Steel Corp. (F)
Revere Copper & Brass Corp. (B)
Ryerson, Joseph T. & Son, Inc. (F)
Sharon Steel Corp. (F)
Thomas Strip Div., Pittsburgh Steel Co. (F)
U.S. Steel Corp. (F)
Weirton Steel Co. (F)
Whitehead Metal Products Co., Inc. (B, F)

PRECOATED METALS—TIN COATED

American Sheet Metal Works, Inc. (F)
Anderson-Bolling Mfg. Co. (F)
Appalachian Steel Corp. (F)
Associated Spring Corp. (F)
Bethlehem Steel Co. (F)
Brasco Mfg. Co. (F)
Caspers Tin Plate Co. (F)
Conner Mfg. Co. (F)
Granite City Steel Co. (F)
Inland Steel Co. (F)
Jones & Laughlin Steel Corp. (F)
Philadelphia Steel & Wire Corp. (F)
Republic Steel Corp. (F)
Riverside Foundry Co. (C)
Somers Brass Co., Inc. (B, E)
U.S. Steel Corp. (F)
Weirton Steel Co. (F)
Youngstown Sheet & Tube Co. (F)

PRE-IMPREGNATED MATERIALS FOR PLASTICS LAMINATES

American Reinforced Plastics Co.
Coast Mfg. & Supply Co.
Cordo Molding Products, Inc.
Flexfirm Products, Inc.
Minnesota Mining & Mfg. Co.
Narmco Resins & Coatings Co.
Raybestos-Manhattan, Inc., Asbestos Textiles Div.
Standard Insulation Co.
Sun Chemical Corp., Electro-Technical Products Div.
U.S. Polymeric Chemicals, Inc.

PREPAINTED METALS

Caspers Tin Plate Co. (A, F)
Clad-Rex Corp. (A, F)
Coated Coil Corp. (A, F, H)
Cooley, W. J. & Co. (A, B, F)
Dow Chemical Co. (D)
Fryling Mfg. Co. (A, F)
Hoofer Mfg. Co. (F)
Mahon, R. C. Co. (F)
Philadelphia Steel & Wire Corp. (F)
Republic Steel Corp. (F)
Reynolds Metals Co. (A)
Rigidized Metals Corp. (A, B, F)
Thomas Strip Div., Pittsburgh Steel Co. (F)

PREPLATED METALS
(chromium, nickel)

Aluminum Specialty Co. (A)
American Nickeloid Co. (A, B, F, H)
American Silver Co., Inc. (B, E, F)
Apollo Metal Works Co.
Benjamin Electric Mfg. Co. (F)

Everard Tap & Die Corp. (A, B, C, F)
Fryling Mfg. Co. (A, B, F, H)
Grand Sheet Metal Products Co., Consumer Products Div. (C)
Kroh Wagner (F)
Metal Trims, Inc. (A)
Rigidized Metals Corp. (A, B, F)
Thomas Strip Div., Pittsburgh Steel Co. (B, E, H)
Wickwire Spencer Steel Div.. Colorado Fuel & Iron Corp. (F)

PRESSED METAL PARTS
(see Formed Metal Shapes)

PROTEIN PLASTICS
Adhesive Products Corp. (18)
American Plastics Corp. (12, 13)
National Casein Sales (17)
Reichhold Chemicals, Inc. (17)

PUNCHED METAL PARTS
(see Stampings)

QUARTZ (see Ceramics)

REFRACTORIES (see Ceramics)

REINFORCED PLASTICS
(see Laminates)

RHENIUM
Chase Brass & Copper Co. (10, 12, 14)
Kennecott Copper Corp.
University of Tenn., Dept. of Chemistry (10)

ROD (see specific material)

ROLLED METAL SHAPES
(see Formed Metal Shapes)

RUBBER (see specific material or form)

SAND CASTINGS (see Castings)

SANDWICH MATERIALS
(key letters refer to core material)
Apex Reinforced Plastics Div., White Sewing Machine Corp. (K)
Armco Steel Corp. (F)
Artmor Plastics Corp. (K)
Busch, J. C. Co. (A)
Cadillac Plastic & Chemical Co. (K)
Chemical Products Corp. (J)
Continental Rubber Works (L)
General Findings & Supply Co., Industrial Div. (B, E)
General Tire & Rubber Co. (K)
Glo-Brite Products, Inc. (K)
H & R Industries (J)
Hardy Mfg. Corp. (F)
Haskelite Mfg. Corp. (J, K, L)
Hawkeye Rubber Mfg. Co. (L)
Hexcel Products, Inc. (A, F, K)
Laragy, P. Iron Foundry, Inc. (C)
Luminous Resins, Inc. (J)
Lunn Laminates, Inc. (K)
Mechanical Rubber Products Co. (K)
Minnesota Mining & Mfg. Co. (K)
National Moldite Co. (C)
National Vulcanized Fibre Co. (K)
Northwest Plastics Industries, Inc. (K)
Quaker Rubber Div., H. K. Porter Co. (K)
Replac Corp. (J, K, L)
Rogers Corp. (K, L)
Russell Reinforced Plastics Corp. (K)
Standard Insulation Co. (K)
Thompson, H. I. Fiber Glass Co. (J)
West Haven Foundry Co. (A, B)
Wittman, Lawrence & Co. (K)
Zenith Plastics Co. (K)

SCREW MACHINE PARTS
Aero Screw Co., Inc. (B, C, F, E)
Aircraft Screw Machine Products Co. (A, B, E, F)
Allied Machine Products Co. (A, B, F)
Allied Metal Products Co. (A, B, F)
Allmetal Screw Products Co., Inc. (E, F, G)
Aluminum Co. of America (A)
American Electrical Products Co. (A, B, E, F)
American Fabricated Products Co. (A, B, E, F)
American Sanitary Mfg. Co. (B)
American Screw Products Co. (A, B, F)
Anti-Corrosive Metal Products Co., Inc. (F)
Approved Mfg. Co., Inc. (F, B)
Ar-Dee Screw Products Co., Inc. (A, B, E, F)
Argosy Products, Inc. (A, B, F)
Ashby Mfg. Co. (B, E, F)
Atlanta Tool Co. (A, B, E, F, G)
Auburn Spark Plug, Inc. (A, B, F)
Auel Industries (A, B, F)
Autel Electronics Co., Precision Machine & Welding Div. (A, B, C, D, F, G)
Automatic Metal Products Corp. (B, E, F, G)
Babson-Dow Mfg. Co. (B, E, F)
Badger Automatic Products Corp. (A, B, E, F)
Balas Collet Mfg. Co. (A, B, E, F)
Baldwin Mfg. Co. (B, A, E, F)
Barton Products Corp. (A, B, E, F)
Bayley Products, Inc. (A, B, F)
Beacon Metal Mfg. Co. (A, B, F, G)
Beck Products Corp. (A, B, E, F)
Bell, David Co., Inc. (A, B, E, F, G)
Bethandale Corp. (A, B, E, F)
Bickford, F. H. Co. (A, B, F)
Biddle Screw Products Co. (A, B, E, F)
Blacher Bros., Inc. (A, B, F)
Boehm Screw Products Co. (B, F)
Brown Corp. (F)
Buchmann Spark-Wheel Corp. (A, B, C, D, E, F)
C & G Screw Machine Products Co. (A, B, F)
Carlton Screw Products Co. (A, B, F)
Carmel Screw Products Co. (B, F, E, G)
Carmichael Machine Co. (A, B, E, F)
Cartwright, R. Tube Products Co. (A, B, F)
Cayce Corp. (A, B, F)
Central Screw Products Co. (A, B, E, F)
Chapman Machine Co., Inc. (A, B, E, F)
Chardon Metal Products Co. (A, B, E, F)
Chase Brass & Copper Co., Inc. (A, B, E)
Chicago Screw Co. (A, B, E, F, G)
Clendenin Bros., Inc. (B)
Cleveland City Forge Co. (C, F)
Cleveland Hardware & Forging Co. (F)
Cleveland Screw Products Co. (A, B, F)
Collis Co. (A, B, E, F)
Columbus Dental Mfg. Co. (A, B, C, F)
Columbus Jack Corp. (B, E, F, G)
Columbus Production Mfg. Co. (A, B, F)
Comerford Mfg. Co., Inc. (A, B, C, D, E, F, G, H)
Condamatic Co., Inc. (A, F, G)
Conn Perry Mfg. Co. (B, F)
Connecticut Mfg. Co. (B, E, F)
Couch-Uthe Co. (B, E, F)
Curtis Screw Co., Inc. (A, B, E, F, G)
Davis & Hemphill (A, B, E, F)
Dawlen Corp. (A, B, C, E)
Decatur Automatic Screw Machine Products Co. (A, B, E, F)
Deerfield Mfg. Co. (A, B, E, F)
Defiance Screw Machine Products Div., Serrick Corp. (F)
Delo Screw Products Co. (A, B, E, F)
Dependable Automatic Screw Co. (A, B, E, F, G)
Drexel Screw Products Co. (A, B, E, F)
Duro Screw & Mfg. Co. (A, B, E, F, G)
Eastern Machine Screw Corp. (A, F)
Economy Machine Products Co. (A, B, E, F)
Electronic Parts Mfg. Co., Inc. (C, F)
Elsby, J. S. Inc. (A, B, E, F)
Erie Bronze Co. (A, B)
Essential Bar Products Co. (A, B, E, F)
Eureka Electrical Products Co. (A, B)
Fairchild Screw Products, Inc. (A, B, E, F)
Falls Machine Co. (A, B, F)
Federal Screw Works (A, B, E, F)
Femco Mfg. Co., Inc. (F)
Fetcher, M. B. Co. (F)
Fischer Special Mfg. Co. (A, B)
Fordsell Machine Products Co. (B, E, F)
Frisby, R. J. Mfg. Co. (A, B, F)
G & G Mfg. Co. (A, B, E, F,)
G & Z Automatic Products Co. (A, B, F)
Gantner Screw Products Co., Inc. (A, B, E, F)
General Engineering Works (A, B, E, F)
General Findings & Supply Co., Industrial Div. (A, B, C, E, F)
General Screw Products Corp. (A, B, E, F)
Grass, M. J. Machine Products Co. (A, B, E, F)
Gregg Metal Products Co. (A, B, E, F)
Gross, Willard N. Inc. (A, B, E, F)
H & H Screw Products, Inc. (A, B, E, F, G)
H. & H. Screw Products Mfg. Co. (A, B, E, F)
H & K Machine Service Co., Inc. (A, B, F)
Haber Corp. (A, B, E, F, G)
Hack, J. H. Mfg. Co. (A, B, E, F)
Hardy Mfg. Corp. (A, B, E, F)
Hartford Machine Screw Co. (A, B, E, F, G)
Harvey Aluminum Div., Harvey Machine Co., Inc. (A, B, E, F, G)
Harvin & Co. (A, B, E, F)
Harwood Screw Products, Inc. (A, B, F)
Held, O. P. Inc. (A, B, F)
Heller, A. B. Screw Products, Inc. (A, B, F)
Henefelt Precision Products (A, B, E, F)
Hercules Fastener Co. (A, C, E, F, H)
Herker Screw Products, Inc. (A, B, F)
Herman Machine & Tool Co. (A, B, E, F)
Hershey Metal Products, Inc. (A, B, E, F, G)
Holt Products Co. (A, F)
Hoofer Mfg. Co. (A, C)
Hoyt, Charles D. Co., Inc. (A, B, E, F)
Huck Mfg. Co. (A)
Hudson Screw Machine Products Co. (A, B, C, D, E, F, G, H)
Hunt Screw & Mfg. Co. (A, B, E, F, G)
Huron Automatic Screw Co. (A, B, F)
Hy-Level Screw Products Co. (A, B, F)
Ideal Metal Products Co. (A, B, E, F)
Imerman Screw Products Co. (F)
Imsande Screw Products Co. (A, B)
Industrial Precision Products (A, B, C)
Industrial Screw Machine Products Co. (A, B, E, F)
Inland Automatic, Inc. (A, B, E, F, G)
Instrument Parts Corp. (A, B, E, F)
Jolens Metal Products Co. (A, B, E, F)
Jordan Machine Products, Inc. (A, B, E, F)
Kay-Bee Machine Products Co. (A, B, F)
Kennedy Automatic Products, Inc. (A, B, E, F, G)
Kenosha Automatic Products Co. (A, B, F)
Kerr-Lakeside Industries, Inc. (A, B, E, F)
Kewaunee Engineering Corp. (C)
Kohn Engineering Corp. (A, B, E, F, G)
Kramer, C. P. Co. (A, B, F)
Lake Mfg. Corp. (A, B, F)
Lamson Products Co. (A, B, E, F)
Lattner Bros. Machining Co. (A, B, E, F)
Latwaitis, Ernest A. (A, B, E, F)
Lawrenceville Screw Co. (A, B, E, F)
Lincoln Machine Parts Corp. (A, B, E, F, G)
Lincoln Mfg. Co. Inc. (A, B, E, F)
Linden & Co., Inc. (A, B, F)
Livingston-Tyler Products (A, B, D, F)

Locke Machine Co. (A, F)
Loeffler, J. M. Co., Machine & Brass Works (A, B, C)
Lorain Automatic Screw Machine Co., Inc. (A, B, F)
Lubenow, Arthur Co. (A, B, E, F)
Lundberg Screw Products Co. (A, B, F)
Lyndon Machine Products Co., Inc. (A, B, F)
M & S Mfg. Co. (A, B, F)
Machine Products Corp. (A, B, C, D, E, F, G, H)
Machinery Products Co. of Lancaster (A, B, E, F)
Machinery Products Corp. (A, B, E, F)
Mac-It Parts Co. (B, E, F)
Main Screw Machine Products, Inc. (A, B, F)
Mantel Screw Products Co. (A, B, E, F, G)
Marquette Metal Products Co. (A, B, E, F)
Masco Screw Products Co. (A, B, E, F)
Massachusetts Screw Mfg. Co. (A, B, E, F)
Maumee Machine & Tool Corp. (A, B, E, F)
Maynard Mfg. Co. (A, B, E, F, G)
McKinney Mfg. Co. (A, B, D, E, F)
McLanahan & Stone Corp. (C, F)
McMahon Bros. Machine Works, Inc. (A, B, E, F, G)
Meaden Screw Products Co. (A, B, E, F)
Measuregraph Co. (A, B, E, F, G)
Mechanical Art Works, Inc. (A, B, E, F)
Meier Screw Products & Mfg. Co. (A, B, C, D, E, F)
Merit Screw Machine Products Co. (A, B, E, F, G)
Merit Specialties Co., Inc. (A, B, D, E, F)
Merz Machine & Tool Works (A, B, E, F)
Micro Products Corp. (A, F)
Mid-West Screw Products Co. (A, B, F)
Midwest Screw Products, Inc. (A, B, E, F, G)
Milford Automatics, Inc. (A, B, F)
Milled Screw Products, Co. (A, B, E, F)
Millers' Brass Fitting Co., Inc. (A, B, F)
Milwaukee Machine Products Co. (A, B, E, F)
Milwaukee Stamping Co. (A, F)
Mitchel & Scott Machine Co., Inc. (A, B, E, F)
Modern Screw Products Co. (B, E, F)
Monarch Tool & Mfg. Co. (F)
Moody Machine Products Co., Inc. (A, B, F)
Moore, George W. Inc. (B, F)
Mueller Brass Co. (A, B, E)
Mueller Machine Products, Inc. (A, B, E, F)
Mutual Screw & Supply Corp. (A, B, C, F)
Napoleon Products Co. (A, B, F)
National Acme Co. (A, B, E, F)
Naugatuck Automatics, Inc. (A, B, F)
New Britain Machine Co. (A, B, F)
New Haven Screw Machine Products, Inc. (A, B, E, F, G, H)
Newtown Mfg. Co. (A, B, E, F, G)
Nicoud Mfg. Co. (A, B, E, F)
Noera Mfg. Co. (A, B, F)
Nolte Screw Machine Products Co. (A, B, E, F)
Northwest Automatic Products Corp. (A, B, E, F, G)
Northwestern Machine Corp. (A, B, E, F)
Nutmeg Screw Machine Products Co. (A, B, E, F)
Ohio Metal Products Co. (A, B, E, F, G)
Ohio Screw Products, Inc. (A, B, E, F)
Olderman Mfg. Corp. (A, B)
Olson Mfg. Co. (A, B, E, F)
Omco Products Corp. (A, B, C, E, F)
Orange Roller Bearing Co. (F)
Ostby & Barton Co., Precision Products Dept., Flightex Fabrics, Inc. (A, B, E, F)
Owen Mfg., Inc. (A, B, E, F)
Pabst Engineering Equipment Co., Inc. (A, B, C, D, E, F, G, H)
Pacific Screw Products Co. (A, B, E, F)
Pan-American Metal Products Co., Inc. (A, B, E, F)
Parker & Harper Mfg. Co. (A, B, E, F)
Peck Spring Co. (A, B, E, F)
Peerless Automatic Machine Co. (A, B, F)
Peerless Industries, Inc. (A, B, F)
Perry Fay Co. (A, B, F)
Phillips, F. C. Inc. (B, E, F)
Phillips Bros. Screw Products Co. (B, E, F, G)
Piper Tool Co., Inc. (A, B, F)
Pohlman, R. L. Co. (A, B, F)
Polyphase Machine Co. (A, B, E, F, G)
Porter Machine Co., Inc. (A, E, F)
Precision Machine Co. (A, B, F)
Precision Piece Parts, Inc. (F)
Precision Screw Products Co., Inc. (A, B, E, F)
Progressive Service Co. (A, B, E, F)
Racine Screw Co. (A, B, E, F)
Rainier Metal Products Co. (A, B, F)
Rasco-Veeder Co. (A, B, E, F)
Ravenswood Machine Corp. (A, B, E, F)
Red Devil Mfg. Co. (B, D, E, F, G)
Redmer Sons Co. (A, B, E, F)
Reliable Screw Machine Products (A, B, E, F, G)
Remler Co., Ltd. (A, B, E, F)
Rex Products Co. (A, B, E, F)
Richmond Mfg. Co. (B, E, F)
Sargent & Greenleaf, Inc. (A, B, F)
Scovill Mfg. Co. (A, B)
Screw Machine Engineering Co., Inc. (A, B, C, E, F)
Searjeant Metal Products, Inc. (A, F)
Seltzer, George H. & Co. (F)
Sharpsville Steel Fabricators, Inc. (F)
Sinclair Co. (A, B, F)
Skookum Co. Inc. (F)
Special Screw Products Co. (A, B, E, F)
Spencer's Sons, I. S. Inc. (B)
Standard Screw Products Co. (A, B, F)
Steel Heddle Mfg. Co. (A, B, C, D, E, F, G, H)
Steel Industries, Inc. (A, B, F)
Textile Shield Co., Inc. (A, B, F)
Thompson Products, Inc. (G)
Titan Metal Mfg. Co. (A, B)
Union Screw & Mfg. Co. (A, B, F)
Unity Machine & Tool Corp. (A, F)
Wagner Specialty Co. (A, B, C, F, H)
Wall, P. Mfg. Co. (A, B, C, F)
Ward, H. H. Co. (A, B, C, E, F, H)
Waterman Industries, Inc. (A, B)
Weber-Knapp Co. (A)
Wedler Bros., Inc. (A, B, E, F)
Western Automatic Machine Screw Co. (A, B, C, D, E, F)
Wirth, Carl, & Son, Inc. (A, B, C, D, E, F, G, H)
Worth Co. (A, B, C, F)
Wuest Bros., Inc. (A, F)
Zeller Corp. (A, F)

SELENIUM

American Metal Co., Ltd. (10)
American Nickel Alloy Mfg. Corp. (10)
Belmont Smelting & Refining Works, Inc. (10)
Federated Metals Div., American Smelting & Refining Co.
Hommel, O. Co. (10)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries, Inc. (7, 8)
Phelps Dodge Refining Corp. (10)

SHEET (see specific material)

SHEET FORMED PLASTICS PARTS (see Moldings, Sheet)

SILICIDES (see Ceramics)

SILICON

Belmont Smelting & Refining Works, Inc. (10)
du Pont de Nemours, E. I. & Co., Inc. (high purity wafers)
Eagle-Picher Co.
Electro Metallurgical Co., Div. of Union Carbide Corp. (10)
Foote Mineral Co. (high purity wafers)
Hardy, Charles Inc. (10)
Lavin, R. & Sons, Inc. (8)
Plastic Metals Div., National-U.S. Radiator Corp. (10)
Sylvania Electric Products, Inc. (12)

SILICON BRONZE (see Copper)

SILICONE PLASTICS

Adhesive Products Corp. (18)
Bakelite Co., Div. Union Carbide Corp. (17, 22)
Barrett Div., Allied Chemical & Dye Corp. (17)
Dow Corning Corp. (17, 18, 21, 22)
General Electric Co., Silicone Products Dept. (13)
Hewitt-Robins, Inc. (21)
Mica Insulator Co. (12, 13)
Mid-States Rubber Products, Inc. (13, 14)
Minnesota Mining & Mfg. Co. (19)
National Vulcanized Fibre Co. (12, 13)
Philrus Products Co. (12, 13, 14)
Raybestos-Manhattan, Inc. (12, 13, 14)
Rogers Corp. (12, 13, 14, 21, 22)
Roth Rubber Co. (13)
Stockwell Rubber Co., Inc. (22, 12, 13, 14)
Synthane Corp. (13, 14)
Taylor Fibre Co. (13)
Union Carbide Corp., Silicones Div. (17)

SILICONE RUBBER

Adhesive Products Corp. (18)
Armstrong Cork Co. (12, 13, 14)
Connecticut Hard Rubber Co. (12, 22, 21, 13, 14)
Continental Rubber Works (22, 12, 13, 14)
Dow Corning Corp. (17, 18, 22)
General Electric Co., Silicone Products Dept. (17)
Goshen Rubber Co., Inc. (22)
Mechanical Rubber Products Co. (20, 21, 12, 13, 14)
Mid-States Rubber Products, Inc. (22, 13, 14)
Minneapolis Honeywell Regulator Co. (21)
Raybestos-Manhattan, Inc. (12, 13, 14)
Stockwell Rubber Co., Inc. (21, 22, 12, 13, 14)
Rogers Corp. (12, 13, 14, 21, 22)
Roth Rubber Co. (13)
Union Carbide Corp., Silicones Div. (17, 18, 22)
U.S. Stoneware Co. (22)

SILVER AND ITS ALLOYS

Alloy Metal Powders, Inc. (10)
Alpha Metals, Inc. (1, 2, 3, 12, 13, 14)
American Metal Co., Ltd. (8, 10)
American Silver Co. (7, 14)
Baker & Co., Inc. (1, 2, 7, 8, 9, 10, 12, 13, 14)
Belmont Smelting & Refining Works Inc. (7, 14)
Bunker Hill Co., Sales & Fabrication Div. (2)
Eastern Smelting & Refining Corp. (10)
Federated Metals Div., American Smelting & Refining Co. (1)
Fox Products Co. (1)
Fulton Gold Refiners Corp. (1, 2, 3, 7, 8, 10, 12, 13, 14)

General Plate Div., Metals & Controls Corp. (1, 7, 9, 12, 13, 14)
Goldsmith Bros., S. & R. Co. (1, 2, 7, 8, 9, 10, 12, 13, 14)
Handy & Harman (1, 2, 7, 8, 9, 10, 12, 13, 14)
Hanovia Chemical & Mfg. Co. (10)
Hardy, Charles Inc. (10)
Hogstoz, T. B. & Son (1, 8, 9, 10, 12, 13, 14)
Leach & Garner Co., Industrial Div. (1, 2, 3, 7, 9, 12, 13, 14)
Metal Goods Corp. (14)
Metals Disintegrating Co. (10)
Minimax Co. (10)
Ney, J. M. Co. (12, 13, 14)
Peerless Roll Leaf Co., Inc. (7, 14)
Sel-Rex Corp. (1, 10)
Western Gold & Platinum Co. (1, 7, 9, 10, 12, 13, 14)
Wildberg Bros. Smelting & Refining Co. (1, 2, 3, 7, 8, 9, 10, 12, 13, 14)
Williams Gold Refining Co. Inc. (1, 2, 3, 7, 8, 9, 10, 12, 14)

SLUSH MOLDINGS (see Moldings)

SPINNINGS

Ace Metal Spinning (A, B, C, D, E, F, G, H)
Acme Metal Spinning, Inc. (A, B, C, D, E, F, H)
Aluminum Goods Mfg. Co. (A)
Aluminum Specialty Co. (A)
Anchor Metal Spinning (A, B, C, D, E, F, G, H)
Bartlett-Thompson Co., Inc. (A, B, E, F)
Bergfels, William & Co. (A, B, C, E, F, H)
Broadway Mfg. Co. (A, B, C, F)
Brooks & Perkins, Inc. (D, G)
Chase Brass & Copper Co. (B)
Commercial Shearing & Stamping Co. (A, B, D, E, F)
Craft Mfg. Co. (A, B, C, D, E, F, G, H)
Cyril Bath Co. (A, F)
Dow Chemical Co. (D)
Emerson-Sack-Warner Corp. (A, B, C. D, E, F, G, H)
Garco Mfg. Co., Inc. (A, B, D, E, F, G, H)
General Alloys Co. (A, B, E, F)
Greene, G. G. Corp. (A, F)
H & H Tube & Mfg. Co. (B)
Hardy Mfg. Corp. (A, F)
Kenmore Machine Products, Inc. (B)
Kling Metal Spinning & Stamping Co. (A, B, C, D, E, F, H)
Legion Utensils Co. (B, E, F)
Morse, Fred W. Co. (A, B, F)
Muncie Metal Spinning, Inc. (A, B, F)
Murray Tube Works, Inc. (A, B, F)
Pabst Engineering Equipment Co., Inc.
Perrin, Edward C. Co. (A, B, F)
Phoenix Products Co. (A, B, C, D, E, F, G, H)
Precision Metal Spinning Co. (A, B, C, D, E, F)
Premier Metal Works, Inc. (A, B, F)
Republic Steel Corp. (F)
Reynolds Metal Co. (A)
Searjeant Metal Products Inc. (A, F)
Seattle Boiler Works, Inc. (A, F)
Smith-Victor Corp. (A)
Spincraft, Inc. (A, B, C, D, E, F, G, H)
Stainless Metals, Inc. (F)
Stirrup Metal Products Corp. (A, B, F)
Teiner, Roland Co., Inc. (A, B, C, D, E, F, G)
Toledo Stamping & Mfg. Co. (A, B, F, G)
Torngren, C. W. Co., Inc. (A, B, C, D, E, F, G, H)
Ward, H. H. Co. (A, B)
Wickwire Spencer Steel Div., Colorado Fuel & Iron Corp. (A, B, E, F, G)

STAMPINGS, PUNCHINGS

Ackermann Mfg. Div., Wheeling Steel Corp. (F)
Acme Mfg. & Gasket Co. (A, B, E, F)
Acme Metal Spinning, Inc. (A, B, C, D, E, F, H)
Acme Stamping & Mfg. Co. (A, B, C, D, E, F)
Acorn Sheet Metal Mfg. Co., Inc. (F)
Acro Metal Stamping Co. (A, B, E, F)
Adams, S. G. Metalware Co. (A, B, C, D, E, F, H)
Aerolite Electronics Corp. (A, B, C, F)
All-Form Metal Products Co. (A, B, C, E, F)
Alloy Products Corp. (F)
Almco Steel Products Corp. (A, B, C, F)
Alofs Mfg. Co. (A, B, E)
Alox Mfg. Co. (A, B, C, E, F)
Alpha Products, Inc. (A, F)
Aluminum Co. of America (A)
Aluminum Goods Mfg. (A)
Aluminum Specialty Co. (A)
American Emblem Co., Inc. (A, B, F)
American Kitchens Div., Avco Mfg. Corp. (F)
American Mfg. Co. (A, F)
American Stamping Co. (A, B, F)
Anchor Metal Co., Inc. (A, H)
Anderson-Bolling Mfg. Co. (A, F)
Anderson, O. L. Co., Inc. (A, B, C, D, E, F, G, H)
Anthes Force Oiler Co. (A, F)
Anti-Corrosive Metal Products Co., Inc. (F)
Armor Metal Products Co. (A, F)
Art Wire & Stamping Co. (A, B, C, D, E, F, G, H)
Associated Spring Corp. (F)
Auburn Mfg. Co. (A, B, C, D, E, F, G, H)
Auel Industries (A, B, E, F)
Auld, D. L. Co. (A, B)
Autel Electronics Co., Precision Machine & Welding Div. (A, B, C, D, F, G)
Backus Novelty Co. (A, B, C, E, F)
Barclay Mfg. Co. (C)
Bartlett-Thompson Co Inc. (A, B, E, F)
Bay State Stamping Co. (A, B, F)
Beacon Metal Mfg. Co. (A, B, F)
Behringer Metal Works, Inc. (A, B, C, F)
Belmet Products, Inc. (A, B, F)
Benjamin Electric Mfg. Co. (F)
Bennett Mfg. Co. (A, B, D, F)
Biersach & Niedermeyer Co. (A, F)
Blacher Bros., Inc. (A, B, F)
Blaco Mfg. Co. (B, F)
Brandt, Charles T. Inc. (A, B, C, E, F)
Brewer-Titchener Corp. (A, F)
Campbell, A. S. Co., Inc. (A, F)
Carroll Pressed Metal Inc. (A, B, E, F)
Cartwright, R. Tube Products Co. (A, B, F)
Chase Brass & Copper Co. (B)
Clendenin Bros. Inc. (A, B)
Cleveland Metal Products Co. (A, B, E, F)
Cleveland Pressed Products Corp. (F)
Cly-Del Mfg. Co., Inc. (A, B, E, F, H)
Columbia Metal Stamping Co. (A, F)
Columbus Dental Mfg. Co. (A, B, C, F)
Comerford Mfg. Co., Inc. (A, B, C, D, E, F, G, H)
Commercial Shearing and Stamping Co. (A, B, E, F)
Cooley, W. J. & Co. (A, B, F)
Craft Mfg. Co. (A, B, C, D, E, F, G, H)
Cuyahoga Stamping Co. (A, B, F)
Cyril Bath Co. (A, D, E, F, G)
Dare Products, Inc. (F)
Dearborn Stamping Co. (F)
Defiance Metal Products Co. (A, F)
Defiance Stamping Co. (F)
Detroit Stamping Co. (A, B, F)
Dolin Metal Products, Inc. (A, F)
Dow Chemical Co. (D)
Duplex Mfg. Corp. (A, F)
Duplicon Co., Inc. (A, B, C, D, E, F, G, H)
Eastern Tool & Mfg. Co. (A, B, F)
Electric Materials Co. (B)
Electronic Parts Mfg. Co., Inc. (C, E, F)
Emerson-Sack-Warner Corp. (A, B, C, D, E, F, G, H)
Empire Spring Co. (A, B, F)
Enamel Products Co. (A, F)
Etched Products Corp. (A, B, F)
Eureka Electrical Products Co. (A, B)
Everard Tap and Die Corp. (A, F)
Falstrom Co. (A, B, D, F)
Farwell Metal Fabricating (A, B, C, D, E, F)
Federal Tool Corp. (A, B, C, F)
Federal Tool & Mfg. Co. (A, B, C, E, F)
Figley Die & Stamping Co. (A, B, F)
FitzSimons Mfg. Co. (A, B, F)
Follansbee Steel Corp., Sheet Metal Specialty Div. (A, B, F)
Forg, Peter Mfg. Co. (A, B, C, E, F, H)
Formold Plastics, Inc. (A, B, F)
Fox Products Co. (C)
Fryling Mfg. Co. (A, B, E, F, H)
Garco Mfg. Co., Inc. (A, B, C, D, E, F, G, H)
Gary Steel Products Corp. (A, F)
General Alloys Co. (A, B, E, F)
General Findings & Supply Co., Industrial Div. (A, B, C, E, F)
Geometric Stamping Co. (A, B, F)
Gerstenslager Co. (A, F)
Geuder, Paeschke & Frey Co. (A, B, C, F)
Grammes, L. F. & Sons, Inc. (A, B, F)
Grand Haven Stamped Products Co. (A, B, F, H)
Grand Sheet Metal Products Co., Consumer Products Div. (A, B, C, D, E, F, G, H)
Greene, G. G. Corp. (A, B, D, E, F, H)
Greene Mfg. Co. (A, F)
Guarantee Specialty Mfg. Co. (A, B, C, F, H)
H P L Mfg. Co. (A, B, F)
Haigh Mfg. Co. (A, B, F)
Hardy Mfg. Corp. (A)
Headly Mfg. Co. (A, B, C, D, E, F, G, H)
Heyman Mfg. Co. (A, B, F)
Hoofer Mfg. Co. (A, F)
Houston Blow Pipe & Sheet Metal Works (A, B, F)
Hunter Spring Co. (B, F)
Indus Corp. (A, F)
Industrial and Furnace Car Div., Irwin Foundry and Mine Car Co. (F)
Industrial Precision Products (A, B, C, D, E, F, G, H)
Interlake Mfg. Co. (A, F)
Irvington Form & Tank Corp. (A, B, F)
Jackson Auto Radiator (A, B, F)
Jarco Metal Products (A, B, F, H)
Judd Industries, Inc. (A, B, F)
K-D Mfg. Co. (F)
Kees, F. D. Mfg. Co. (A, B, C, F)
Kickhaefer Mfg. Co. (A, B, F)
King Laboratories, Inc. (E, F)
Kirchhof Patent Co., Inc. (A, B, C, E, F, H)
Kling Metal Spinning & Stamping Co. (A, B, C, D, E, F, H)
Krueger & Hudepohl Inc. (A, B, C, E, F)
Larkin Specialty Mfg. Co. (A, B, F)
Larson Tool & Stamping Co. (A, B, C, D, E, F, G, H)
Laystrom Mfg. Co. (A, B, C, E, F, H)
Leake Stamping Div., Monarch Products Co. (A, B, E, F, G)
Legion Utensils Co. (B, E, F)
Linden & Co., Inc. (A, B, F)
Lynn, Gary Co. (A, B, F)
Machine Products Corp. (A, B, C, D, F)
Magnesium Co. of America (D)
Magnetic Stamping Co. (A, B, F)
Mayville Metal Products Co. (A, B, F)
McDowell Mfg. Co. (A, B, F)
McKinney Mfg. Co. (A, B, D, E, F)
McLanahan & Stone Corp. (C, F)
Melco Wire Products (A)
Metal Forming Corp. (A, B, C, D, E, F, G, H)

Metal Parts & Stamping Co. (A, B, C, E, F, G, H)
Metallurgical Products Co. (A, B, E, G, H)
Milwaukee Stamping Co. (A, B, F)
Misner Corp. (A, B, C, F)
Mitchell Metal Products, Inc. (F)
Monarch Tool & Mfg. Co. (A, B, F)
Morrison Steel Products, Inc. (F)
Morse, Fred W. Co. (A, B, D, E, F, G, H)
Nichols, L. O. & Son Mfg. Co. (A, B, C, E, F, H)
Nigg Engineering Corp. (A, B, C, F)
Noera Mfg. Co. (A, B, F)
Norcross, C. S. & Sons Co. (F)
Ohio Nut & Washer Co. (A, F)
Ormond Mfg. Co., Inc. (A, B, C, E, F, H)
Pabst Engineering Equipment Co., Inc. (A, B, C, D, E, F)
Parish Pressed Steel Div., Dana Corp. (A, F, G)
Parker, Charles Co. (A, E)
Parker Metal Goods Co. (A, B, F)
Pemco Wheel Co. (F)
Penrod, Floyd & Sons Tool & Engineering Corp. (A, B, F)
Peterson Products Corp. (A, B, E, F)
Pierce Governor of Ohio Inc. (A, F)
Pittsburgh Forgings Co. (F)
Powell Pressed Steel Co. (A, F)
Premier Metal Works, Inc. (A, B, E, F)
Presswork Inc. (A, B, F)
Reed & Prince Mfg. Co. (A, B, F)
Regal Ware, Inc. (A, B, F)
Reliable Spring & Wire Forms Co. (A, B, E, F)
Republic Steel Corp. (F, G)
Rex Metal Parts Co. (A, F)
Reynolds Metals Co. (A)
Rochester Novelty Works Inc. (A, F)
Rockwell Spring & Axle Co. (A, B, C, D, E, F, G, H)
Rogers Dayton Mfg. Co. (A, B, F)
Roth Steel Products Co. (F)
St. Marys Carbon Co. (A, B, E, F)
Salem Tool Co. (F)
Sargent & Greenleaf, Inc. (A, B, F)
Scovill Mfg. Co. (A, B)
Searjeant Metal Products Inc. (F)
Servwell Products Co. (B, F)
Shakeproof Div., Illinois Tool Works (B, F)
Shank Metal Products Co. (A, F)
Sheet Metal Mfg. Co. (A, F)
Shelby Mfg. Co. (F)
Simonsen Metal Products Co. (A, F)
Sinclair Co. (B, F)
Sioux City Foundry & Boiler Co. (F)
Smith-Victor Corp. (A, F)
South River Metal Products Co., Inc. (A, D, F)
Southern Car & Mfg. Co., Inc. (A, B, F)
Spincraft, Inc. (A, B, F)
Stainless Metals, Inc. (F)
Stamford Metal Specialty Co., Inc. (A, E, F)
Standard Forge & Axle Co., Inc. (F)
Standard Nut & Bolt Co. (A, B, E, F)
Standard Steel Sections, Inc. (A, B, C, F)
Starr Stamping Co. (A, B, F)
Staver Co., Inc. (A, B, C, D, E, F, G, H)
Steel Heddle Mfg. Co. (A, B, C, D, E, F, G, H)
Steel Industries, Inc. (A, B, F)
Stenman, Bror F. (A, F)
Stimpson, Edwin B. Co., Inc. (A, B, E, F, H)
Stirrup Metal Products Corp. (A, B, F)
Textile Shield Co., Inc. (A, B, F)
Toledo Stamping & Mfg. Co. (A, B, F, G)
Transue-Williams (A, E, F)
Triangle Stamping Co. (A, B, C, E, F, H)
Turner & Seymour Mfg. Co., Inc. (A, B, F)
United Metal Products Corp. (A, B, F)
U.S. Gasket & Shim Co. (A, B, C, D, F, H)
Unity Machine & Tool Corp. (A, B, F)
Victor Steel Products Corp. (F)
Von Volkenburg, L. A. Co. (A, F)
WLS Stamping Co. (A, B, D, E, F, H)
Wagner, E. R. Mfg. Co. (A, B, C, F, H)
Wagner Specialty Co. (A, B, C, F, H)
Wall, P. Mfg. Co. (A, B, F)
Ward, H. H. Co. (A, B, C, E, F, H)
Waterbury Buckle Co. (A, F, H)
Waterbury Companies, Inc. (B, F)
Waterman Industries, Inc. (A, B, F)
Wayne Foundry & Stamping Co. (A, B, C, D, F, G)
Weber-Knapp Co. (A, F)
Welding Apparatus Co. (A, E, F)
Wesbar Stamping Corp. (A, F)
Wesco Spring Co. (A, B, F)
Western Tool & Die Works (A, B, F)
Wilder Mfg. Co., Inc. (A, B, C, F)
Williams, F. B. (F)
Williams, H. E. Products Co. (A, B, C, F, H)
Wirth, Carl & Son, Inc. (A, B, F)
Wisconsin Gasket & Mfg. Co. (A, B, F)
Wood, John Co. (F)
Woolf Aircraft Products, Inc. (A, B, F)
Worcester Pressed Steel Co. (A, B, C, D, E, F, G, H)
Worcester Stamped Metal Co. (A, B, E, F, G, H)
Worth Co. (A, B, D, F)
Wrought Wire Mfg. Co. (A, B, D, E, F, H)
Wuest Bros., Inc. (A, B, C, F)
Youngstown Kitchens Div., American Standard Co. (A, F)
Youngstown Mfg., Inc. (A, F)

STEATITE (see Ceramics)

STEEL, CARBON

Acme-Newport Steel Co. (8, 9, 13)
Alan Wood Steel Co. (9, 13, 14)
Alco Products, Inc. (3)
Allegheny Ludlum Steel Corp. (14)
Alloy Metal Powders, Inc. (10)
Almco Steel Products Corp. (2, 9, 12, 13, 14)
Amalgamated Steel Corp. (2, 12)
American Metal Products, Inc. (13)
Ames, W. & Co. (2)
Armco Steel Corp. (2, 9, 13)
Athenia Steel Co. (14)
Bethlehem Steel Co. (2, 3, 9, 12, 13, 14)
Bliss & Laughlin, Inc. (2)
Cannon-Muskegon Corp. (3, 8)
Colorado Fuel and Iron Corp. (9, 12)
Copperweld Steel Co. (2, 3, 8)
Crucible Steel Co. of America (2, 3, 8, 9, 12, 13, 14)
Detroit Steel Corp., Portsmouth Div. (3, 8, 12, 13)
Enterprise Wheel & Car Corp. (2, 9, 13)
Franklin Steel Div., Borg-Warner Corp. (2)
Frasse, Peter A. & Co. (2, 13)
Gary Steel Products Corp. (2, 9, 13)
Granite City Steel Co. (8, 9, 13)
Inland Steel Co. (2, 3, 9, 12, 13, 14)
Isaacson Iron Works (3, 8)
K-D Mfg. Co. (2)
Keystone Drawn Steel Co. (2)
Keystone Steel & Wire Co (8, 12)
Larson, Charles E. & Sons, Inc. (2)
La Salle Steel Co. (2)
Levinson Steel Co. (2, 9, 12, 13, 14)
Lockport Mfg. Co. (9)
Lukens Steel Co. (9)
Luria Engineering Co. (9, 12, 13)
Mahon, R. C. Co. (2, 9, 12, 13, 14)
McCarter Iron Works, Inc. (2, 9, 12, 13)
McInnes Steel Co. (2)
McLouth Steel Corp. (13, 14)
Midvale-Heppenstall Co. (3, 8)
Mitchell Metal Products, Inc. (9, 13)
Newman-Crosby Steel Co. (14)
New York Iron Roofing & Corrugating Co., Inc. (13)
Pacific States Steel Corp. (2, 3, 8)
Pacific Tube Co. (2)
Pittsburgh Forgings Co. (2, 3)
Pittsburgh Steel Co. (1, 8, 12, 13, 14)
Porter, H. K. Co., Inc. (2, 3)
Republic Steel Corp. (2, 3, 8, 9, 12, 13, 14)
Roebling's Sons, John A. Corp. (3, 12, 14)
Rome Strip Steel Co., Inc. (13, 14)
Ross-Meehan Foundries (2)
Ryerson, Joseph T. & Son, Inc. (2, 9, 13, 14)
St. Louis Steel Casting Inc. (1)
Sandvik Steel, Inc. (14)
Sharon Steel Corp. (13, 14)
Sharpsville Steel Fabricators, Inc. (2, 9, 12, 13)
Siegal Steel Co. (2, 12, 13, 14)
Simonds Saw and Steel Co. (13, 14)
Smith-Moon Steel Co. (2, 9, 12, 13, 14)
Standard Steel Works Div., Baldwin-Lima-Hamilton Corp. (2, 3)
Superior Drawn Steel Co. (2)
Superior Steel Corp. (14)
Sweet's Steel Co. (2)
Thompson Wire Co. (14)
Thomson Industries, Inc. (12)
Topeka Foundry & Iron Works Co., Inc. (2, 9, 12, 13, 14)
Trojan Steel Co. (2, 9, 12, 13, 14)
Union Iron Works (9, 12, 13, 14)
U.S. Challenge & Challenge Co. (12)
U.S. Steel Corp. (2, 3, 8, 9, 12, 13, 14)
Vacuum Metals Corp., Div. Crucible Steel Co. of America (2, 3, 8, 12, 13, 14)
Vanadium-Alloys Steel Co. (2, 3, 8, 9, 10, 12, 13)
Washburn Wire Co., Phillipsdale Div. (3, 12, 14)
Weirton Steel Co. (3, 13, 14)
Western Automatic Machine Screw Co. (2)
Western Iron & Foundry Co., Inc. (2, 9, 12, 14)
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp. (8, 9)
Wyckoff Steel Co. (2)
Youngstown Sheet & Tube Co. (2, 12, 13, 14)

STEEL, CARBON—CASTINGS

Adirondack Foundries & Steel, Inc.
Allied Steel Castings Co.
Alloy Cast Steel Co.
Alloy Precision Castings Co.
Alloy Steel & Metals Co.
American Cast Iron Pipe Co.
American Steel Foundries
Arneson Foundry, Inc.
Arwood Precision Casting Corp.
Atlantic Foundry Co.
Auto Specialties Mfg. Co.
Beaver Valley Alloy Foundry Co.
Bethlehem Steel Co.
Birdsboro Steel Foundry & Machine Co.
Calumet Steel Castings Corp.
Campbell, Wyant and Cannon Foundry Co., Div. of Textron, Inc.
Continental Foundry & Machine Co.
Crucible Steel Casting Co.
Crucible Steel Co. of America
Dayton Steel Foundry Co.
Eastern Malleable Iron Co.
Electric Steel Castings Co.
Electric Steel Foundry Co.
Farrel-Birmingham Co., Inc.
Federal Steel Products Corp.
General Electric Co., Foundry Dept.
Glover Machine Works
Gunite Foundries Corp.
Hughes Tool Co.
Illinois Precise Casting Co.
Jones & Laughlin Steel Corp.

Bold face indicates supplier advertises product in this issue

Kay-Brummer Steel Products, Inc.
L F M Mfg. Co., Inc.
Lebanon Steel Foundry
Lectromelt Casting Div., Akron Standard Mold Co.
Los Angeles Steel Casting Co.
Mackintosh-Hemphill Div., E. W. Bliss Co.
Minneapolis Electric Steel Casting Co.
National Iron Co.
National Supply Co.
Ohio Steel Foundry Co.
Oklahoma Steel Castings Co.
Olympic Steel Works
Omaha Steel Works
Pittsburgh Steel Foundry Corp.
Posey Iron Works, Inc.
Pratt & Letchworth Div., Dayton Malleable Iron Co., Inc
Racine Steel Castings Co.
Reliance Steel Casting Co.
Ross-Meehan Foundries
St. Louis Steel Casting Inc.
Sandusky Foundry and Machine Co.
Scullin Steel Co.
Sharpsville Steel Fabricators, Inc.
Sivyer Steel Casting Co.
Skookum Co., Inc.
Standard Steel Works Div., Baldwin-Lima-Hamilton Corp.
Strong Steel Foundry Co.
Superior Steel & Malleable Castings Co.
Swedish Crucible Steel Co.
Texas Foundries, Inc.
Texas Steel Co.
Union Iron Works
Union Spring & Mfg. Co.
Unitcast Corp.
Valley Steel Casting Co.
Vulcan Iron Works
Washington Iron Works
Westlectric Castings, Inc.
Worthington Corp.

STEEL, HEAT AND CORROSION RESISTANT

Alco Products, Inc. (3)
Allegheny Ludlum Steel Corp. (2, 3, 9, 12, 13, 14)
Alloy Metal Powders, Inc. (10)
Alloy Metal Products, Inc. (3, 8)
American Silver Co., Inc. (7, 14)
Armco Steel Corp. (2, 3, 8, 9, 12, 13, 14)
Bethlehem Steel Corp. (2, 9, 12, 13, 14)
Cannon-Muskegon Corp. (2, 3, 8, 13)
Carlson, G. O. Inc. (2, 9)
Carpenter Steel Co. (2, 3, 8, 12, 14)
Crucible Steel Co. of America (2, 3, 8, 9, 12, 13, 14)
Eastern Stainless Steel Corp. (9, 13)
Frasse, Peter A. & Co., Inc. (2, 3, 13, 14)
Gary Steel Products Corp. (2, 9, 13)
Hardy, Charles Inc. (10)
Hoeganaes Sponge Iron Corp. (10)
Krueger Fabricating Co., Inc. (13)
Larson, Charles E. & Sons Inc. (2)
Latrobe Steel Co. (2, 3, 8)
Lockport Mfg. Co. (9)
Lukens Steel Co. (9)
McCarter Iron Works Inc. (2, 9, 12, 13)
McInnes Steel Co. (2)
Midvale-Heppenstall Co. (3, 8)
Mitchell Metal Products, Inc. (13)
New Jersey Metals Co. (8)
Penn Precision Products, Inc. (7, 14)
Republic Steel Corp. (2, 3, 8, 9, 12, 13, 14)
Ross-Meehan Foundries (2)
Ryerson, Joseph T. & Son, Inc. (2, 9, 13, 14)
Sandvik Steel, Inc. (14)
Sharon Steel Corp. (13, 14)
Sharpsville Steel Fabricators, Inc. (2, 9, 12, 13)
Simonds Saw and Steel Co. (13, 14)
Smith-Moon Steel Co. (2, 9, 13, 14)
Superior Steel Corp. (14)
Timken Roller Bearing Co. (2, 3)
U.S. Challenge & Challenge Co. (12)
U.S. Steel Corp. (2, 3, 6, 8, 9, 12, 13, 14)
Vacuum Metals Corp., Div. Crucible Steel Co. of America (2, 3, 8, 12, 13, 14)
Vanadium-Alloys Steel Co. (10)
Wallingford Steel Co. (7, 14)
Washington Steel Corp. (13, 14)
Whitehead Metal Products Co., Inc. (9, 12, 13, 14)

STEEL, HEAT AND CORROSION RESISTANT—CASTINGS

Adirondack Foundries & Steel, Inc.
Allegheny Ludlum Steel Corp.
Alloy Precision Castings Co.
American Brake Shoe Co.
American Cast Iron Pipe Co.
American Steel Foundries
Apex Steel Corp., Ltd.
Arwood Precision Casting Corp.
Babcock & Wilcox Co.
Beaver Valley Alloy Foundry Co.
Blaw Knox Co., National Alloy Div.
Bonney-Floyd Co.
Calorizing Co.
Campbell, Wyant and Cannon Foundry Co., Div. of Textron, Inc.
Carondelet Foundry Co.
Cooper Alloy Corp.
Crucible Steel Casting Co.
Crucible Steel Co. of America
Curtiss-Wright Corp.
Donegal Steel Foundry Co.
Driver-Harris Co.
Duraloy Co.
Duriron Co., Inc.
Electric Steel Foundry Co.
Electro Alloys Div., American Brake Shoe Co.
Fahralloy Co.
Frasse, Peter A. & Co., Inc.
General Alloys Co.
Hanford Foundry Co.
Illinois Precise Casting Co.
Ingersoll-Rand Co.
Janney Cylinder Co.
Lebanon Steel Foundry
Los Angeles Steel Casting Co.
Michigan Steel Casting Div., Consolidated Foundries & Mfg. Corp.
Ohio Steel Foundry Co.
Oklahoma Steel Castings Co.
Pittsburgh Steel Foundry Corp.
Quaker Alloy Casting Co.
Ross-Meehan Foundries
Sandusky Foundry and Machine Co.
Sharpsville Steel Fabricators, Inc.
Shawinigan Chemicals Ltd.
Sivyer Steel Casting Co.
Skookum Co., Inc.
Stainless Foundry & Engineering, Inc.
Stanwood Corp.
Symington-Gould Corp.
Union Iron Works
U.S. Pipe & Foundry Co.
Welland Electric Steel Foundry Ltd.
Westalloy Div., West Steel Casting Co.

STEEL, LOW ALLOY

Acme-Newport Steel Co. (9, 13, 14)
Alan Wood Steel Co. (9, 13, 14)
Alco Products, Inc. (3)
Amalgamated Steel Corp. (2, 12)
Bethlehem Steel Co. (2, 9, 12, 13, 14)
Bliss & Laughlin, Inc. (2)
Cannon-Muskegon Corp. (2, 3, 8, 13)
Copperweld Steel Co. (2, 3)
Crucible Steel Co. of America (2, 3, 8, 9, 12, 13, 14)
Enterprise Wheel & Car Corp. (9, 13)
Frasse, Peter A. & Co., Inc. (2)
Great Lakes Steel Corp. (2, 9, 12, 13)
Hardy, Charles Inc. (10)
Hoeganaes Sponge Iron Corp. (10)
Keystone Drawn Steel Co. (2)
Larson, Charles E. & Sons Inc. (2)
La Salle Steel Co. (2)
Levinson Steel Co. (9, 13)
Lincoln Steel Corp. (13)
Lukens Steel Co. (6, 9)
McInnes Steel Co. (2)
Midvale-Heppenstall Co. (3, 8)
Pittsburgh Forgings Co. (2, 3)
Plastic Metals Div., National Radiator Co. (10)
Porter, H. K. Co., Inc. (2, 3)
Republic Steel Corp. (2, 3, 8, 9, 12, 13, 14)
Ross-Meehan Foundries (2)
St. Louis Steel Casting Inc. (1)
Sandvik Steel, Inc. (14)
Sharon Steel Corp. (13, 14)
Sharpsville Steel Fabricators, Inc. (2, 9, 12, 13)
Sheffield Div., Armco Steel Corp. (9, 14)
Simonds Saw and Steel Co. (13, 14)
Smith-Moon Steel Co. (2, 9, 13)
Standard Steel Works Div., Baldwin-Lima-Hamilton Corp. (2, 3)
Thompson Wire Co. (14)
Union Iron Works (12)
U.S. Steel Corp. (2, 3, 8, 9, 12, 13, 14)
Vacuum Metals Corp., Div. Crucible Steel Co. of America (2, 3, 8, 12, 13, 14)
Vanadium-Alloys Steel Co. (10)
Washburn Wire Co., Phillipsdale Div. (3, 12, 14)
Western Automatic Machine Screw Co. (2)
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp. (8, 9)
Wyckoff Steel Co. (2)
Youngstown Sheet & Tube Co. (2, 12, 13, 14)

STEEL, LOW ALLOY—CASTINGS

Adirondack Foundries & Steel, Inc.
Allied Steel Castings Co.
Alloy Cast Steel Co.
Alloy Precision Castings Co.
Alloy Steel & Metals Co.
American Brake Shoe Co.
American Cast Iron Pipe Co.
American Manganese Steel Div., American Brake Shoe Co.
American Steel Foundries
Arwood Precision Casting Corp.
Atlantic Foundry Co.
Auto Specialties Mfg. Co.
Beaver Valley Alloy Foundry Co.
Birdsboro Steel Foundry & Machine Co.
Campbell, Wyant and Cannon Foundry Co., Div. of Textron, Inc.
Carondelet Foundry Co.
Crucible Steel Casting Co.
Crucible Steel Co. of America
Dayton Steel Foundry Co.
Electric Steel Castings Co.
Electric Steel Foundry Co.
Federal Steel Products Corp.
General Electric Co., Foundry Dept.
Glover Machine Works
Grafton Foundry Co.
Gunite Foundries Corp.
Hughes Tool Co.
Illinois Precise Casting Co.
Jones & Laughlin Steel Corp.
L F M Mfg. Co., Inc.
Lebanon Steel Foundry
Lectromelt Casting Div., Akron Standard Mold Co.
Los Angeles Steel Casting Co.
Mackintosh-Hemphill Div., E. W. Bliss Co.
Minneapolis Electric Steel Castings Co.
National Iron Co.
National Supply Co.

Oklahoma Steel Castings Co.
Olympic Steel Works
Omaha Steel Works
Pittsburgh Steel Foundry Corp.
Pratt & Letchworth Div., Dayton Malleable Iron Co., Inc.
Reliance Steel Casting Co.
Ross-Meehan Foundries
St. Louis Steel Casting Inc.
Sandusky Foundry and Machine Co.
Sharpsville Steel Fabricators, Inc.
Sivyer Steel Casting Co.
Strong Steel Foundry Co.
Swedish Crucible Steel Co.
Texas Foundries, Inc.
Texas Steel Co.
Union Iron Works
Union Spring & Mfg. Co.
Unitcast Corp.
Valley Steel Casting Co.
Vulcan Iron Works
Washington Iron Works
Westlectric Castings, Inc.
Worthington Corp.

STEEL, SPECIALTY
(electrical, magnet, nitriding, etc.)

Acme-Newport Steel Co. (13)
Allegheny Ludlum Steel Corp. (2, 13, 14)
Alloy Metal Powders, Inc. (10)
Amalgamated Steel Corp. (2, 12)
American Silver Co., Inc. (7, 12)
Cannon-Muskegon Corp. (2, 3, 8, 13)
Carpenter Steel Co. (2, 3, 8, 12, 14)
Crucible Steel Co. of America (2, 3, 8, 9, 12, 13, 14)
Hoeganaes Sponge Iron Corp. (10)
Inland Steel Co. (13)
Larson, Charles E. & Sons Inc. (2)
La Salle Steel Co. (12)
Latrobe Steel Co. (2, 3, 8)
McInnes Steel Co. (2)
Midvale-Heppenstall Co. (3, 8)
Penn Precision Products, Inc. (7, 14)
Republic Steel Corp. (13, 14)
Ryerson, Joseph T. & Son, Inc. (2)
Sandvik Steel, Inc. (2, 12, 14)
Simonds Saw and Steel Co. (13, 14)
Stulz-Sickles Co. (2, 3, 9, 12)
Superior Steel Corp. (14)
Timken Roller Bearing Co. (2, 3)
U.S. Steel Corp. (2, 3, 8, 9, 12, 13, 14)
Vacuum Metals Corp., Div. of Crucible Steel Co. of America (2, 3, 8, 12, 13, 14)
Vanadium-Alloys Steel Co. (10)

STEEL, SPECIALTY—CASTINGS

Allegheny Ludlum Steel Corp.
Alloy Precision Castings Co.
Arwood Precision Casting Corp.
Carondelet Foundry Co.
Crucible Steel Casting Co.
Crucible Steel Co. of America
Electric Steel Foundry Co.
Janney Cylinder Co.
Los Angeles Steel Casting Co.
Stulz-Sickles Co.

STEEL, TOOL AND DIE

Able Tool & Engineering Co. (9)
Allegheny Ludlum Steel Corp. (2, 3, 9, 12)
Amalgamated Steel Corp. (2, 12)
Cannon-Muskegon Corp. (2, 3, 8, 13)
Carpenter Steel Co. (2, 3, 8, 12, 14)
Columbia Tool Steel Co. (2, 3, 8, 12)
Crucible Steel Co. of America (2, 3, 8, 9, 12, 13, 14)
Delaware Tool Steel Corp. (2)
Frasse, Peter A. & Co., Inc. (2)
Heller Tool Co. (2)
Kidd Drawn Steel Co. (2, 12)
Larson, Charles E. & Sons Inc. (2)
Latrobe Steel Co. (2, 3, 8)
Midvale-Heppenstall Co. (3, 8)
Pittsburgh Tool Steel Wire Co. (2, 12)
Republic Steel Corp. (2, 9, 12)
Ross-Meehan Foundries (2)
Ryerson, Joseph T. & Son, Inc. (2, 3, 12, 13)
Sharpsville Steel Fabricators, Inc. (12)
Simonds Saw and Steel Co. (2, 13, 14)
Timken Roller Bearing Co. (2, 3)
Vacuum Metals Corp., Div. of Crucible Steel of America (2, 3, 8, 12, 13, 14)
Vanadium-Alloys Steel Co. (2, 3, 8, 9, 10, 12, 13)
Vulcan Crucible Steel Div., H. K. Porter Co., Inc. (2, 3, 8, 12)

STEEL, TOOL AND DIE—CASTINGS

Allegheny Ludlum Steel Corp.
Alloy Precision Castings Co.
Apex Steel Corp., Ltd.
Arwood Precision Casting Corp.
Beaver Valley Alloy Foundry Co.
Carondelet Foundry Co.
Crucible Steel Casting Co.
Crucible Steel Co. of America
Illinois Precise Casting Co.
Ross-Meehan Foundries

STRIP (see specific material)

STYRENE (see Polystyrene)

STYRENE-BUTADIENE RUBBER

American Hard Rubber Co. (12, 13, 14)
American Synthetic Rubbber Corp. (17)
Auburn Plastics Inc. (12, 13, 14)
Auburn Rubber Co., Inc. (13)
Borden Co., Chemical Div. (17)
Chicago Molded Products Corp., Campco Div. (13)
Continental Rubber Works (22, 12, 13, 14)
Copolymer Rubber and Chemical Corp. (17)
Firestone Tire & Rubber Co. (17)
Geauga Industries Co. (22, 12, 14)
General Tire & Rubber Co. (17)
Goodrich, B. F. Chemical Co. (17)
Goodrich-Gulf Chemicals, Inc. (17)
Goodyear Tire & Rubber Co. (17)
Goshen Rubber Co., Inc. (22)
Heresite & Chemical Co. (17)
Home Rubber Co. (22, 12, 13, 14)
Koppers Co., Inc. (17)
Marbon Chemical Div., Borg-Warner Corp.
Mid-States Rubber Products, Inc. (22, 13, 14)
Naugatuck Chemical Div., U.S. Rubber Co. (17)
Parker, Stearns & Co., Inc. (13, 14)
Phillips Chemical Co. (17)
Roth Rubber Co. (22, 13)
Rubatex Div., Great American Industries, Inc. (21)
Shell Chemical Corp. (17)
Southern Plastics Co. (12, 13, 14)
Stockwell Rubber Co., Inc. (22, 12, 13, 14)
Technical Specialties Co. (14)
Texas-U.S. Chemical Co. (17)
United Rubber & Chemical Co. (17)
Vulcanized Rubber & Plastics Co. (22)
Westlake Plastics Co. (12, 13, 14, 20)

SYNTHETIC FIBERS
(see specific polymer)

TANTALUM AND ITS ALLOYS

Alpha Metals, Inc. (7, 13, 14)
Belmont Smelting & Refining Works, Inc. (8)
Columbia National Corp. (8)
Fansteel Metallurgical Corp. (1, 2, 8, 9, 10, 12, 13, 14)
General Plate Div., Metals & Controls Corp. (7, 14)
Hardy, Charles Inc. (10)
Kennametal, Inc. (10)
Metal Hydrides, Inc. (10)
Shieldalloy Corp. (10)

TEFLON (see Fluorocarbons)

TERNE PLATE (see Precoated Metals)

TETRAFLUOROETHYLENE
(see Fluorocarbons)

TINPLATE (see Precoated Metals)

TIN AND ITS ALLOYS

Alpha Metals, Inc. (1, 2, 3, 7, 8, 10, 12, 13, 14)
Belmont Smelting & Refining Works, Inc. (1, 2, 7, 8, 10, 13, 14)
Bridgeport Rolling Mills Co. (13, 14)
Bunker Hill Co., Sales & Fabrication Div. (1, 2, 8)
Chicago Smelting & Refining Corp. (8)
Crown Non-Ferrous Foundry Inc. (8)
Division Lead Co. (1, 2, 3, 7, 8, 10, 12, 13, 14)
Federated Metals Div., American Smelting & Refining Co. (1, 2, 3, 8)
Fox Products Co. (1)
Glidden Co. (10)
Greenback Industries, Inc. (10)
Hardy, Charles Inc. (10)
Hodgson Foundry Co. (1)
Kirk, Morris P. & Son, Inc. (1, 2, 10, 12)
Lavin, R. & Sons, Inc. (1, 8)
McGean Chemical Co. (1, 10)
Metal & Thermit Corp. (1, 3, 8)
Metals Disintegrating Co., Inc. (10)
National Lead Co. (10)
New England Brass Co. (13, 14)
New England Smelting Works, Inc. (2)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (7, 8)
Oatey, L. R. Co. (2, 3, 8, 12, 13, 14)
Peerless Alloy Co. (2, 8, 12)
Pittsburgh Smelting & Refining Co. (8)
Republic Metals Co., Inc. (1, 2, 7, 8, 12, 13, 14)
River Smelting & Refining Co. (8)
Riverside-Alloy Metal Div., H. K. Porter Co., Inc. (12, 13, 14)
Rotometals (2, 7, 8, 10)
Sel-Rex Corp. (10)

TITANIUM AND ITS ALLOYS

Alpha Metals, Inc. (7)
American Silver Co. (7, 14)
Belmont Smelting & Refining Works, Inc. (8)
Driver-Harris Co. (7, 14)
du Pont de Nemours, E. I. & Co., Inc. (sponge)
Electro Metallurgical Co., Div. of Union Carbide Corp. (10)
Firth Sterling Inc. (2, 3, 8, 12, 14)
Foote Mineral Co. (2)
General Plate Div., Metals & Controls Corp. (7, 14)
Hardy, Charles Inc. (10)
Harvey Aluminum Div., Harvey Machine Co., Inc. (2, 3, 8, 12)
King Laboratories, Inc. (8, 10)
Mallory-Sharon Titanium Corp. (2, 3, 9, 12, 13, 14)
Metal Hydrides Inc. (8, 10)
Metals Disintegrating Co., Inc. (10)

National Lead Co. (10)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (7, 8)
Pioneer Aluminum Inc. (9)
Rem-Cru Titanium, Inc. (2, 3, 7, 8, 9, 12, 13, 14)
Republic Steel Corp. (2, 3, 8, 9, 12, 13, 14)
Rigidized Metals Corp. (13, 14)
Superior Steel Corp. (14)
Titanium Metals Corp. of America (2, 3, 9, 10, 12, 13, 14)
U.S. Industrial Chemicals Co., Div. of National Distillers Co. (sponge)
United International Research, Inc. (10)
Vacuum Metals Corp., Div. of Crucible Steel Co. of America (2, 3, 8, 9, 13, 14)

TRANSFER MOLDINGS
(see Moldings)

TRIFLUOROCHLOROETHYLENE
(see Fluorocarbon)

TUBING, PIPE
Ace Plastic Co. (J, K)
Acme-Newport Steel Co. (F)
Albert Pipe Supply Co., Inc. (A, F)
Albright Son & Co. (F)
Allegheny Ludlum Steel Corp. (F)
Allied Tube Corp. (A, F)
Alpha Plastics Inc. (J)
Aluminum Co. of America (A, D)
Amco Plastic Pipe Co. (J)
American Agile Corp. (J)
American Brass So. (A, B, F)
American Cast Iron Pipe Co. (C, F)
American Hard Rubber Co. (J, K, L)
American Metal Hose Div., American Brass Co. (A, B, F)
American Molding Co. (J)
American Plastics Corp. (J)
American Reed Co., Inc. (A)
Anchor Plastics Co., Inc. (J)
Anesite Co. (J)
Apex Reinforced Plastics Div., White Sewing Machine Corp. (K)
Armco Steel Corp. (E)
Atlas Mineral Products Co. (J)
Auburn Plastic Engineering (J)
Avon Tube Div., Higbie Mfg. Co. (F)
Babcock & Wilcox Co., Tubular Products Div. (C, F, G)
Bassons Industries Corp. (J)
Benada Aluminum Products Co. (A)
Bethlehem Steel Co. (F)
Bishop, J. & Co., Platinum Works (E, F)
Blackman, Horace Co. (J)
Bohn Aluminum & Brass Corp. (A)
Borden Co., Chemical Div. (J)
Bridgeport Brass Co. (A, B)
Brinkerhoff Brass & Bronze Works, Inc. (A, B, E, F)
Broadway Mfg. Co. (C, F)
Burkhardt Steel Co. (F)
Busada Mfg. Corp. (J)
Cadillac Plastic & Chemical Co. (J, K)
Calfibe Co., Inc. (J)
Carlon Products Corp. (J)
Carpenter Steel Co., Alloy Tube Div. (F, G)
Cartwright, R. Tube Products Co. (A, B, D, E, F)
Celluplastic Corp. (J)
Chase Brass & Copper Co. (B)
Chemical Products Corp. (J)
Chicago Gasket Co. (J)
Clayton Mark & Co. (F)
Colonial Art Co., Inc. (J)
Colonial Plastics Mfg. Co. (J)
Colorado Fuel & Iron Corp. (F)
Commercial Plastics & Supply Corp. (J, K)
Conneaut Rubber & Plastics Co. (J, L)
Connecticut Hard Rubber Co. (L)
Continental Can Co., Inc. (J)
Continental Copper & Steel Industries Inc. (A, B, C, D, E, F, G)
Continental Rubber Works (L)
Continental-Diamond Fibre Corp., Div. of Budd Co.
Cornell & Underhill, Inc. (A, C, F)
Crane Co. (J)
Crescent Plastics, Inc. (J)
Crucible Steel Co. of America (F, G)
CrystalX Corp. (J)
Curtiss-Wright Corp. (F, G)
Damascus Tube Co. (F)
Defiance Metal Products Co. (F)
Detroit Float & Stamping Co. (B)
Dixie Aluminum Corp. (A)
Dixie Plastics Mfg. Co. (J)
Dixon Corp. (J)
Dormont Mfg. Co. (A, B, E, F)
Dow Chemical Co. (D)
Drawn Metal Tube Co. (B)
Dryden Rubber Div., Sheller Mfg. Co. (L)
Easton Plastic Products Co., Inc. (J)
Eclipse Plastic Industries, Inc. (J)
Electric Steel Foundry Co. (E, F)
Electronic Parts Mfg. Co., Inc. (E)
Fibercast Corp. (K)
FitzSimons Mfg. Co. (F)
Flexaust Co., Div. of Callahan Zinc-Lead Co., Inc. (L)
Flexonics Corp. (F)
Florence Pipe Foundry & Machine Co. (C)
Formed Tubes Inc. (F)
Fox Products Co. (A)
Franklin Plastics, Inc. (J)
Frasse, Peter A. & Co., Inc. (A, F, G)
Fromson Orban Co., Inc. (A, B, E)
Garlock Packing Co. (J)
Gates Rubber Co. (J)
Geauga Industries Co. (L)
General Plastics Corp. (J)
Genesee Laboratories, Inc. (J)
Gering Products, Inc. (J)
Glass Laboratories, Inc. (J)
Goodrich, B. F. Industrial Products Co. (J)
H & H Tube & Mfg. Co. (A, B)
H-P Products, Inc. (F)
Hall Mfg. Corp. (J)
Hartwell, H. M. & Son, Inc. (J)
Harvey Aluminum Div., Harvey Machine Co., Inc. (A)
Hawkridge Bros. Co. (A)
Hays Mfg. Co. (K)
Hazledine, E. T. Co. (F)
Heil Process Equipment Corp. (J)
Houston Blow Pipe & Sheet Metal Works (A, B, F)
Hungerford Plastics Corp. (J)
Hussey, C. G. & Co., Div. of Copper Range Co. (B)
Hydrawlik Co. (J, L)
Imco Container Corp. (J)
Industrial Pipe & Supply Co. (F)
Industrial Plastic Fittings Co. (J)
Industrial Synthetics Corp. (J)
International Metal Hose Co. (F)
International Nickel Co., Inc. (E)
Irvington Chemical Co. (J)
Jackson Steel Products, Inc. (A, B, F)
Jet Specialties Co., Inc. (J)
Johnson Metal Hose, Inc. (B, E)
Johnson Plastic Corp. (J, L)
Johnson Rubber Co. (L)
Jones & Laughlin Steel Corp. (F)
Jordan-Rogers Co. (J)
Judsen Rubber Works, Inc. (L)
KSH Plastics, Inc. (J)
Kaiser Aluminum & Chemical Sales, Inc. (A)
Kensico Tube Co. (B)
Kleiner Metal Specialties, Inc. (F)
Kraloy Plastic Pipe Co., Inc. (J)
Kroh Wagner (A, F)
Laclede Steel Co. (F)
Langsenkamp, F. H. Co. (A, B)
Leach & Garner Co., Industrial Div. (A, B, E)
Lee Rubber & Tire Corp. (L)
Lewin-Mathes Co. (B)
Lewis & Saunders (A, B, F)
Linderme Tube Co. (A, B)
Lock Joint Tube Co. (F)
Lunn Laminates, Inc. (K)
Luzerne Rubber Co. (J, L)
MacKenzie-Walton Co. (B)
Makepeace, D. E. Co. (A, B, E, F)
Manufacturers Corp. (J)
Manufacturers & Fabricators, Inc. (F)
Mechanical Rubber Products Co. (K)
Mechanical Steel Tubing Corp. (A, B, C, D, E, F, G, H)
Meier Screw Products & Mfg. Co. (A, B, C, D, F)
Melco Wire Products (A)
Metal Forming Corp. (E, F, G)
Metal Goods Corp. (A, B, F)
Midland Pipe & Supply Co. (B, C, F)
Midvale-Heppenstall Co. (F)
Minnesota Mining & Mfg. Co. (J, K)
Missouri Boiler & Sheet Iron Works (F)
Moore Dry Dock Co. (F)
Morse, Fred W. Co. (A)
Mueller Brass Co. (B)
Murray Tube Works, Inc. (A, B, E, F)
Nalge Co. Inc. (J)
National Copper & Smelting Co. (B)
National Gasket & Washer Mfg. Co., Inc. (J, K, L)
National Supply Co. (F)
National Tube Div., U.S. Steel Corp. (F)
National Vulcanized Fibre Co. (K)
New England Tape Co., Inc. (J)
Nikoh Tube Co. (F)

KEY

MATERIALS

A—Aluminum and its alloys
B—Copper and its alloys
C—Iron and its alloys (except steel)
D—Magnesium and its alloys
E—Nickel and its alloys
F—Steels
G—Titanium and its alloys
H—Zinc and its alloys
J—Thermoplastics
K—Thermosetting plastics
L—Elastomers

BASIC FORMS

1—Anodes
2—Bar
3—Billets
7—Foil
8—Ingot
9—Plate
10—Powder
12—Rod
13—Sheet
14—Strip
17—Base resins, polymers or gums
18—Laminating or casting resins
19—Fibers or filaments
20—Film
21—Foams (component materials or products)
22—Molding compounds
23—Tube, nonmetallic (except plastics or rubber)

Noera Mfg. Co. (B, F)
Ohio Seamless Tube Div., Copperweld Steel Co. (F)
Ohio Steel Foundry Co. (E)
Pabst Engineering Equipment Co., Inc. (A, B, C, D, E, F, G, H)
Parker, Stearns & Co., Inc. (L)
Penn Brass & Copper Co. (A, B)
Perfex Plastics, Inc. (J)
Pfister Aluminum Corp. (A)
Pittsburgh Steel Co. (F)
Plastex Co. (J)
Plastic Pipe & Tube Corp. (J)
Plastic Process Co., Inc. (J)
Polyform Plastics Corp. (J)
Polymer Corp. (J)
Porter, William Co. (K)
Precision Extrusions, Inc. (A)
Precision Tube Co., Inc. (A, B, E, F)
Prima Pipe Co. (J)
Prince Rubber Co., Inc. (J, L)
Pyramid Moldings Inc. (F)
Pyramid Plastics, Inc. (J, L)
Quaker Rubber Div., H. K. Porter Co. (J, K, L)
Raybestos-Manhattan, Inc. (L)
Reading Tube Corp. (B)
Reflin Co. (J)
Reinhold Engineering & Plastics Co. (J)
Reliance Plastic & Chemical Corp. (J)
Rem-Cru Titanium, Inc. (G)
Ren Plastics, Inc. (K)
Replac Corp. (J, K, L)
Republic Steel Corp. (F, G, J)
Resin Industries (J)
Resistoflex Corp. (J)
Revere Copper & Brass, Inc. (A, B, F)
Rex Corp. (J)
Reynolds Metals Co. (A)
Rigidized Metals Corp. (A, F)
Roll Formed Products Co. (A, F, H)
Rome Turney Radiator Co. (A, B, F)
Roth Steel Products Co. (F)
Rowland Products, Inc. (J)
Ryerson, Joseph T. & Son, Inc. (F)
Sandusky Foundry & Machine Co. (B, E, F)
Sandvik Steel, Inc. (F)
Schwab Plastic Corp. (J, L)
Scovill Mfg. Co. (B)
Searjeant Metal Products Inc. (F)
Service Steel Co. (F)
Shamban, W. S. & Co. (J)
Sharpsville Steel Fabricators, Inc. (B, F)
Shaw-Kendall Engineering Co. (F)
Shoe Form Co. (J)
Sierra Electric Corp. (J)
Skyline Industries (J)
Small Tube Products Inc. (B)
Snyder, M. L. & Son, Inc. (J)
South River Metal Products Co., Inc. (A, D)
Southern Plastics Co. (J, L)
Southwestern Plastic Pipe Co. (J)
Sparta Mfg. Co., Div. of U.S. Ceramic Tile Co. (J)
Spiral-Glas Pipe Co. (J)
Standard Products Co. (L)
Standard Tube Co. (F)
Stockwell Rubber Co., Inc. (J, L)
Stokes Molded Products, Div. of Electric Storage Battery Co. (J)
Sunlite Plastics, Inc. (J)
Superior Tube Co. (E, F, G)
Supplex Co., Div. of American Hard Rubber Co. (J, L)
Surprenant Mfg. Co. (J)
Swepco Tube Corp. (A, E, F, G)
Synthane Corp. (K)
Taylor Fibre Co.
Technical Specialties Co. (L)
Texas Aluminum Co. (A)
Thompson Pipe & Steel Co. (E, F)
Timken Roller Bearing Co. (F)
Titanium Metals Corp. of America (G)
Torrington Co. (A, F)
Trent Tube Co. (E, F, G)
Triangle Conduit & Cable Co., Inc. (B, J)
Tube Methods, Inc. (F)
Tube Reducing Corp. (C, E, F, G)
Tube Turns Plastics, Inc. (J)
Udylite Corp. (J)
Uniform Tubes, Inc. (A, B, E, F)
Union Steel Corp. (F)
U.S. Gasket Co. (J)
U.S. Rubber Co., Mechanical Goods Div. (J)
U.S. Stoneware Co. (J)
U.S. Valve & Mfg. Co. (F)
United Wire & Supply Corp (A, B)
Van Huffel Tube Corp. (A, B, F)
Viking Copper Tube Co. (B)
Viplax Products Corp. (J)
Visking Co., Plastics Div. (J)
Vogt Mfg. Corp. (J)
Vulcan Metal Products, Inc. (A)
Vulcan Rail & Construction Co. (A, C, F)
Wallingford Steel Co. (F)
Wal-Mar Corp. (A, B, C, F)
Wayne Brass Co. (A, B)
Weiskittel, Harry C. Co., Inc. (C)
Welding Apparatus Co. (A, E)
Wells, A. H. & Co., Inc. (B)
Western Plastics Corp. (J)
Westlake Plastics Co. (J, K, L)
Wheeling Steel Corp. (F)
White Metal Rolling & Stamping Corp. (D)
Whitehead Metal Products Co., Inc. (A, B, E, F, G)
Wolverine Tube Div., Calumet & Hecla, Inc. (A, B, F)
Woolf Aircraft Products, Inc. (A, B, F)
World Plastex (J, L)
Yardley Plastics Co. (J)
Youngstown Mfg., Inc. (A)
Youngstown Sheet & Tube Co. (F)

TUNGSTEN

Associated Engineering & Mfg. Corp. (2, 10, 12, 13, 14)
Belmont Smelting & Refining Works (10)
Cleveland Tungsten, Inc. (10)
Electro Metallurgical Co., Div. of Union Carbide Corp. (10)
Fansteel Metallurgical Corp. (2, 8, 9, 10, 12, 13, 14)
General Electric Co., Lamp Wire & Phosphors Dept. (10)
Gibson Electric Co. (10)
Hardy, Charles Inc. (10)
Sylvania Electric Products, Inc. (8, 10, 12)
Westinghouse Electric Corp., Lamp Div.

UREAS

American Cyanamid Co., Plastics & Resins Div. (17, 21)
Archer-Daniels-Midland Co. (17)
Bakelite Co., Div. of Union Carbide Corp. (17, 18)
Barrett Div., Allied Chemical & Dye Corp. (22)
Booty Resineers, Inc. (17)
Borden Co., Chemical Div. (17, 22)
Catalin Corp. of America (17)
Colton Chemical Co., Div. of Air Reduction Co., Inc. (21)
Dunnican Associates (22)
du Pont de Nemours, E. I. & Co., Inc. (17)
Farley & Loetscher Mfg. Co., Plastics Div. (13)
Gordon Chemicals Inc. (22)
Mica Insulator Co. (12, 13)
Monsanto Chemical Co. (17)
Muehlstein, H. & Co., Inc. (17, 22)
Omni Products Corp. (22)
Reichhold Chemicals, Inc. (17, 18, 21)
Sylvan Plastics Inc. (22)
Synco Resins, Inc. (17)
Texas Glass Fiber Corp. (22)

URETHANE PLASTICS

Adhesive Products Corp. (18)
American Rubber Products Corp. (21, 12, 13, 14)
Atlas Mineral Products Co. (21)
Barrett Div., Allied Chemical & Dye Corp. (21)
Crest Chemical Industries Corp. (21)
Disogrin Industries, Inc. (13)
du Pont de Nemours, E. I. & Co., Inc. (17, 21)
Foamade Industries (21)
Furane Plastics Inc. (18, 21)
General Tire & Rubber Co. (21, 13, 14)
Hewitt-Robins, Inc. (21)
Isocyanate Products, Inc. (21)
Luminous Resins, Inc. (22)
Mobay Chemical Co. (17, 21)
Nesbit Industries, Inc. (21)
Nopco Chemical Corp. (21)
Rubber Corp. of America (21)
Russell Reinforced Plastics Corp. (21)
Schenectady Varnish Co. Inc. (17)
Schwab Plastics Corp. (21)
Strick Plastics Co. (21)
Thiokol Chemical Corp. (17, 21)
U.S. Rubber Co. (21)

URETHANE RUBBER

Adhesive Products Corp. (18)
American Rubber Products Corp. (21, 12, 13, 14)
Brown Rubber Co., Inc. (21)
Continental Rubber Works (22, 12, 13, 14)
Disogrin Industries, Inc. (13)
du Pont de Nemours, E. I. & Co., Inc. (17, 21)
Foamade Industries (21, 22, 13)
General Tire & Rubber Co. (21)
Isocyanate Products, Inc. (21)
Mobay Chemical Co. (17, 21, 22)
Quaker Rubber Div., H. K. Porter Co. (21)
Rubber Corp. of America (21)
Schwab Plastics Corp. (21)
Technical Specialties Co. (14)
Thiokol Chemical Corp. (17, 21)
U.S. Rubber Co. (21)

VACUUM FORMED PARTS

(see Moldings, Sheet)

VANADIUM

Belmont Smelting & Refining Works, Inc. (10)
Electro Metallurgical Co., Div. of Union Carbide Corp. (8)
General Plate Div., Metals & Controls Corp. (7)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (7, 8)
Vanadium Corp. of America (8)

VINYLS

Adhesive Products Corp. (18)
Albany Novelty Mfg. Co. (20)
Alpha Plastics Inc. (12, 14)
American Agile Corp. (12, 13, 14)
American Hard Rubber Co. (12, 13, 14)
American Molding Powder & Chemical Co. (22)
American Products Mfg. Co. Inc. (17)
Atlas Mineral Products Co. (12, 13)
Auburn Plastic Engineering (13)
Bakelite Co., Div. of Union Carbide Corp. (17, 18, 20, 21, 22)
Bamberger, Claude P. Inc. (22)
Blossom Mfg. Co., Inc. (20, 12, 13)
Borden Co., Chemical Div. (17)
Brown Rubber Co., Inc. (21)
Cadillac Plastic & Chemical Co. (20, 13, 14)
Carroll, J. B. Co. (13)
Cary Chemicals, Inc. (22)

Chemical Products Corp. (21, 22)
Colonial Art Co., Inc. (13)
Colonial Plastics Mfg. Co. (12, 13)
Colton Chemical Co., Div. of Air Reduction Co., Inc. (17)
Commercial Plastics & Supply Corp. (12, 13, 14)
Conneaut Rubber & Plastics Co. (22, 12, 13, 14)
Crest Chemical Industries Corp. (21)
Dennis Chemical Co. (18, 21)
Douglas & Sturgess (18)
Dow Chemical Co. (17, 18)
du Pont de Nemours, E. I. & Co., Inc. (17)
Dura Flex Co. (13, 20)
Elastomer Chemical Corp. (22)
Federal Adhesives Corp. (21, 22)
Firestone Plastics Co. (17, 18, 19, 20, 13)
Franklin Glue Co. (17)
Fry Plastics Co. (12, 13, 20)
Fullerton Mfg. Co. (22)
Geauga Industries Co. (12, 14)
Genesee Laboratories, Inc. (17)
Gering Products, Inc. (22, 12, 14)
Goodrich, B. F. Industrial Products Co. (20, 12, 13, 14)
Goodyear Tire & Rubber Co., Inc. (17, 18)
H & R Industries (12, 13, 14)
Hartwell, H. N. & Son, Inc. (12, 13)
Haskelite Mfg. Corp. (13, 14)
Hydrawlik Co. (12, 14)
Industrial Plastics Corp. (12, 14)
Interchemical Corp. (17, 21)
KSH Plastics, Inc. (12, 13, 14)
Kaykor Industries, Inc. (12, 13)
Kuss, R. L. & Co., Inc. (20)
Luminous Resins, Inc. (22)
Masland Duraleather Co. (20)
Monsanto Chemical Co. (13, 17, 18, 20, 22)
Naugatuck Chemical Div., U.S. Rubber Co. (17, 22)
New England Tape Co., Inc. (21, 22, 12, 13, 14)
Nixon Nitration Works (12, 13)
Omni Products Corp. (13, 17, 20, 22)
O'Sullivan Rubber Corp. (13)
Perfex Plastics, Inc. (12, 14)
Polo Plastics Co. (20)
Pyramid Plastics, Inc. (12, 13, 14)
Pyrosil, Inc. (13)
Rand Rubber Co. (17, 18, 20)
Reichhold Chemicals, Inc. (17, 18)
Reliance Plastic & Chemical Corp. (12, 14)
Resistoflex Corp. (12, 13)
Rezolin, Inc. (20)
Rubatex Div., Great American Industries, Inc. (21)
Schwab Plastics Corp. (21, 12, 14)
Seaman Products (13, 20)
Seiberling Rubber Co., Plastics Div. (13)
Shawinigan Resins Corp. (17)
Snyder Mfg. Co., Inc. (20, 13)
Southern Plastics Co. (12, 13, 14)
Stockwell Rubber Co., Inc. (22, 12, 13, 14)
Supplex Co., Div. of American Hard Rubber Co. (22, 12, 14)
Synco Resins, Inc. (17)
Texas Plastic Development Corp. (12)
U.S. Stoneware Co. (22, 12, 13, 14)
Visking Co., Plastics Div. (20)
Vogt Mfg. Corp. (12, 14)
Walsen Consolidated Mercantile Co. (13, 20)
World Plastex (12, 13, 14)

VINYLIDENE CHLORIDE (see Vinyls)

VITREOUS COATINGS (see Coatings)

VULCANIZED FIBRE

Ace Plastic Co. (12, 13)
Cadillac Plastic & Chemical Co. (12, 13, 14)
Commercial Plastics & Supply Corp. (12, 13, 14)
Continental-Diamond Fibre Corp., Div. of Budd Co. (12, 13, 14)
Coyne & Paddock Inc. (13)
Iten Fibre Co. (12, 13, 14)
National Vulcanized Fibre Co. (12, 13, 14)
Penn Fibre & Specialty Co., Inc. (21, 12, 13, 14)
Philrus Products Co. (12, 13, 14)
Spaulding Fibre Co., Inc. (12, 13, 14)
Taylor Fibre Co. (12, 13)
Westlake Plastics Co. (12, 13, 14)
Wilmington Fibre Specialty Co. (12, 13)

WELDMENTS

Acme Precision Products, Inc. (A, E, F)
Acorn Sheet Metal Mfg. Co., Inc. (F)
Adams, I. G. Metalware Co. (F)
Albert Pipe Supply Co., Inc. (A, F)
Alco Products, Inc. (A, B, E, F)
Allis-Chalmers Mfg. Co. (A, E, F)
Alloy Products Corp. (F)
Almco Steel Products Corp. (A, B, C, F)
Aluminum Co. of America (A)
Amalgamated Steel Corp. (F)
American Brake Shoe Co. (B)
American Cast Iron Pipe Co. (C, F)
American Metal Products Co. (A, F)
American Pipe & Construction Co. (A, F)
American Welding & Mfg. Co. (A, F)
Anderson, O. L. Co., Inc. (A, B, C, D, F)
Armor Metal Products Co. (A, F)
Atlas Steel Construction Co. (A, B, C, F)
Baldwin-Lima-Hamilton Corp. (A, F)
Barclay Mfg. Co. (C)
Beatty Machine & Mfg. Co. (F)
Behringer Metal Works, Inc. (A, F)
Beloit Iron Works (C, F)
Bergen Point Iron Works (A, E, F)
Bethlehem Steel Co. (F)
Biersach & Niedermeyer Co. (A, F)
Blaw-Knox Co. (A, F)
Brandt, Charles T. Inc. (A, B, C, E, F)
Brooks & Perkins, Inc. (D, G)
Butler Mfg. Co. (A, F)
Caldwell, W. E. Co. (A, F)
Central Fabricators, Inc. (A, B, C, E, F, G)
Chase Brass & Copper Co. (B)
Chicago Bridge & Iron Co., Div. of U.S. Steel Corp. (A, F)
Clarksville Foundry & Machine Works (A, C)
Cleveland Steel Specialty Co. (F)
Cleveland Welding Div., American Machine & Foundry Co. (A, C, E, F, G)
Combined Industries Co. (A, B, C, D, E, F)
Combustion Engineering, Inc. (A, B, F)
Commercial Shearing and Stamping Co. (F)
Composite Forgings, Inc. (F)
Consolidated Western Steel Div., U.S. Steel Corp. (F)
Continental Copper & Steel Industries Inc. (A, B, C, D, E, F, G)
Cornell and Underhill, Inc. (A, F)
Darby Corp. (A, E, F)
Dare Products, Inc. (F)
Day Co. (A, C, F)
Dixie Bronze Co. (B)
Dow Chemical Co. (D)
Downingtown Iron Works (C, F)
Dravo Corp. (A, F)
Dresser Mfg. Div., Dresser Industries, Inc. (A, E, F)
Electric Steel Foundry Co. (F)
Emerson-Sack-Warner Corp. (A, B, C, D, E, F, G, H)
Falstrom Co. (A, B, C, D, F)
Farwell Metal Fabricating (A, B, C, D, E, F)
Fitzgibbons Boiler Co., Inc. (A, F)
Foster Wheeler Corp. (A, E, F)
Gary Steel Products Corp. (A, F)
General American Transportation Corp., Plate & Welding Div. (A, E, F)
General Alloys Co. (A, B, C, E, F)
Glasby, J. P. Mfg. Co., Inc. (A, D, F)
Graver Tank & Mfg. Co. (A, F)
Greene, G. G. Corp. (F)
Hazledine, E. T. Co. (F)
Hibben & Co. (A, F)
Hicks Corp. (A, B, F)
Hobbs, Clinton E. Co. (C, F)
Houston Blow Pipe & Sheet Metal Works (A, B, F)
Ideal Can Co. (A, F)
Industrial Equipment Co. (A, F)
Industrial Pipe & Supply Co. (F)
Industrial Precision Products (A, C)
Ingalls Iron Works Co. (C, F)
Interlake Mfg. Co. (F)
Irvington Form & Tank Corp. (A, B, F)
K-D Mfg. Co. (C, F)
Kaiser Aluminum & Chemical Sales, Inc. (A)
Kewaunee Engineering Corp. (C)
Koven, L. O. & Brother, Inc. (A, F)
Krueger Fabricating Co., Inc. (A, B, C, D, F)
Larkin Specialty Mfg. Co. (A, B, F)
Lawrence, L. Co., Inc. (A, B, C, D, E, F, G, H)
Leader Iron Works, Inc. (A, B, E, F)
Levinson Steel Co. (F)
Lincoln Steel Corp. (F)
Lockport Steel Fabricators, Inc. (A, E, F)
Loeffler, J J. Co., Machine & Brass Works (A, B, C)
Lukens Steel Co. (E, F)
Machine Products Corp. (A, B, C, D, E, F, G, H)
Magline, Inc. (A, D)
Mahon, R. C. Co. (F)
Manufacturers & Fabricators, Inc. (F)
Mayville Metal Products Co. (F)
McLanahan & Stone Corp. (F)
McNally Pittsburg Mfg. Co. (A, C, F)
Midvale-Heppenstall Co. (F)
Midwest Piping Co., Inc. (F)
Missouri Boiler & Sheet Works (F)
Moore Dry Dock Co. (F)
Murray Tube Works, Inc. (F)
National Steel & Shipbuilding Corp. (F)
National Tank Co. (A, F)
Nigg Engineering Corp. (A, C, F)
Pabst Engineering Equipment Co., Inc. (A, C, E, F)
Parish Pressed Steel Div., Dana Corp. (A, F)
Patterson Foundry & Machine Co. (A, F)
Pennsylvania Engineering Corp. (F)
Penrod, Floyd & Sons Tool & Engineering Corp. (F)
Pfaudler Co. (A, E, F)
Portland Co. (F)
Posey Iron Works, Inc. (F)
Pressed Steel Tank Co. (A, E, F)
Pusey & Jones Corp. (A, B, C, D, E, F)
Rankin Forge Co. (C, F)
Republic Steel Corp. (F)
Reynolds Metals Co. (A)
Rockwell Spring & Axle Co. (A, C, F)
Rolock, Inc. (E)
Rose Iron Works (A, B, C, E, F, G)
Rosedale Foundry & Machine Co. (F)
Scaife Co. (A, F)
Seattle Boiler Works, Inc. (A, E, F)
Shank Metal Products Co. (A, F)
Shriver, T. & Co., Inc. (A, F)
Sinclair Co. (B, C, F)
Sioux City Foundry & Boiler Co. (F)
Smith Corp., A. O. (A, F)
South River Metal Products Co., Inc. (A, D, F)
Southern Car & Mfg. Co., Inc. (A, F)
Spincraft, Inc. (A, B, F)
Spring City Foundry Co. (C)
Stacey Mfg. Co. (A, F)
Stainless Metals, Inc. (F, G)
Standard Steel Sections, Inc. (A, C, F)
Steel, R. & Sons, Inc. (F)
Stover Steel Tank & Mfg. Co. (F)
Struthers Wells Corp. (F)

Texas Foundries, Inc. (F)
Thompson Pipe & Steel Co. (A, B, E, F)
Toledo Stamping & Mfg. Co. (F)
Torngren, C. W. Co., Inc. (A, B, C, E, F, G)
Trane Co. (F)
Union Iron Works (F)
Union Tank Car Co. (A, E, F)
U.S. Valve & Mfg. Co. (F)
Victor Steel Products Corp. (F)
Vulcan Mfg. Div. (A, B, E, F, G)
Wal-Mar Corp. (A, C, F)
Ward, H. H. Co. (A, B, C, E, F, H)
Waterman Industries, Inc. (F)
Weilman Engineering Co. (F)
Western Foundry & Machine Works, Inc. (F)
Whyte, Oliver Co., Inc. (A, C, F)
Wickwire Spencer Steel Div., Colorado Fuel and Iron Corp. (F)
Wilder Mfg. Co., Inc. (C, F)
Willamette Iron and Steel Co. (E, F)
Wyatt Metal and Boiler Works (A, F)

WIRE

Ace Wire Spring & Form Co., Inc. (F)
Allegheny Ludlum Steel Corp (F)
All-State Welding Alloys Co., Inc. (A, B, D, E, F, H)
Alpha Wire Corp. (B)
Aluminum Co. of America (A, D)
American Brass Corp. (B)
American Chain & Cable Co., Inc. (F)
American Electric Cable Co. (B, C, F)
American Reed Co., Inc. (C)
Armco Steel Corp. (C, F)
Associated Spring Corp. (F)
Atlantic Bag Co. (F)
Belmont Smelting & Refining Works, Inc. (H)
Bethlehem Steel Co. (F)
Bristol Brass Corp. (B)
Cambridge Wire Cloth Co. (A, B, C, D, E, F, G)
Carol Cable Co., Div. of Crescent Co., Inc. (B)
Carpenter Steel Co. (F)
Chase Brass & Copper Co. (B)
Cincinnati Pump & Mfg. Co., Inc. (F)
Clendenin Bros. Inc. (A, B)
Colorado Fuel and Iron Corp. (F)
Comerford Mfg. Co., Inc. (A, B, C, D, E, F, G, H)
Continental Steel Corp. (F)
Crucible Steel Co. of America (F, G)
Dare Products, Inc. (B, F)
Detroit Steel Corp., Portsmouth Div. (F)
Driver, Wilbur B. Co. (E)
Driver-Harris Co. (B, E, G)
Electric Steel Foundry Co. (F)
Electronic Parts Mfg. Co., Inc. (B, E)
Elgin National Watch Co. (E)
Empire Metal Co. (H)
Erskine Precision Wire Corp. (E)
Essex Wire Corp. (A, B)
Frasse, Peter A. & Co., Inc. (A, F)
General Alloys Co. (A, B, E, F)
Greene, G. G. Corp. (F)
Haven-Busch Co. (F)
Hawkridge Bros. Co. (A, G)
Hayden Wire Works, Inc. (B, E)
Hazledine, E. T. Co. (F)
Hudson Wire Co. (B)
Indiana Steel & Wire Co., Inc. (F)
International Nickel Co., Inc. (E)
Jarco Metal Products (F)
Jelliff, C. O. Mfg. Corp. (E)
Johnson Steel and Wire Co., Inc. (F)
Jones & Laughlin Steel Corp. (F)
Kaiser Aluminum & Chemical Sales, Inc. (A)
Keystone Steel & Wire Co. (F)
Langsenkamp, F. H. Co. (A, B)
LaSalle Steel Co. (F)
Leach & Garner Co., Industrial Div. (A, B, E)
Lincoln Steel Corp. (F)
Little Falls Alloys Inc. (A, B, G)
Macwhyte Co. (F)
Mallory-Sharon Titanium Corp. (G)
Matthiessen & Hegeler Zinc Co. (H)
Melco Wire Products (A)
Metal Goods Corp. (A, B, E)
Mid-West Wire Products Co., Inc. (F)
Murdock Mfg. Co., Inc. (B)
National Electric Products Corp. (B)
Nesor Alloy Products Co. (A, B, C, E, F, G, H)
New England Electrical Works, Inc. (B)
Nichols Wire & Aluminum Co. (A)
Philadelphia Steel & Wire Corp. (F)
Pittsburgh Steel Co. (F)
Rem-Cru Titanium, Inc. (G)
Republic Steel Corp. (F)
Reynolds Metals Co. (A)
Reynolds Wire Div., National-Standard Co. (A, B, E, F, G)
Riverside-Alloy Metal Div., H. K. Porter Co. (A, C, F)
Rolock, Inc. (E)
Ryerson, Joseph T. & Son, Inc. (F)
Sandvik Steel, Inc. (F)
Scovill Mfg. Co. (A, B)
Seneca Wire & Mfg. Co. (F)
Sharpsville Steel Fabricators, Inc. (F)
South River Metal Products Co., Inc. (A)
Stulz-Sickles Co. (F)
Sylvania Electric Products Inc. (C, E, F)
Titan Metal Mfg. Co. (B)
Tyler, W. S. Co. (A, B, E, F)
United Wire & Supply Corp. (A, B)
Utility Mfg. Co. (A, B, F)
Wal-Mar Corp. (A, F)
Washburn Wire Co., Phillipsdale Div. (F)
Wesco Spring Co. (A, B, F)
Whitehead Metal Products Co., Inc. (A, B, E, F)
Whyte, Oliver Co., Inc. (A, F)
Wickwire Bros. Inc. (F)

WIRE FORMS AND PARTS

Ace Wire Spring & Form Co., Inc. (F)
Acme Stamping & Mfg. Co. (A, B, F)
All-Form Metal Products Co. (A, B, C, E, F)
Alox Mfg. Co. (A, B, C, E, F)
Aluminum Co. of America (A)
American Mfg. Co. (A, F)
American Reed Co., Inc. (C)
American Steel & Wire Div., U.S. Steel Corp. (F)
Anthes Force Oiler Co. (F)
Armco Steel Corp. (F)
Art Wire & Stamping Co. (A, B, C, D, E, F, G, H)
Associated Spring Corp. (F)
Bethlehem Steel Co. (F)
Blacher Bros., Inc. (B, F)
Blaco Mfg. Co. (F)
Buffalo Wire Works Co. (A, B, E, F)
Cambridge Wire Cloth Co. (A, B, E, F)
Carpenter Steel Co. (F)
Cartwright, R. Tube Products Co. (B)
Cincinnati Pump & Mfg. Co., Inc. (F)
Clendenin Bros. Inc. (A, B, F)
Cleveland Metal Products Co. (A, B, E, F)
Cleveland Wire Spring Co. (F)
Colorado Fuel and Iron Corp. (F)
Columbus Dental Mfg. Co. (F)
Comerford Mfg. Co., Inc. (A, B, C, D, E, F, G, H)
Dare Products, Inc. (F)
Eastern Tool & Mfg. Co. (A, B, F)
Electronic Parts Mfg. Co., Inc. (B, E)
Elgin National Watch Co. (E)
Empire Spring Co. (F)
Farwell Metal Fabricating (A, B, C, D, E, F)
Figley Die & Stamping Co. (F)
Fryling Mfg. Co. (A, B, C, F)
General Alloys Co. (A, B, E, F)
General Findings & Supply Co., Industrial Div. (A, B, C, E)
Grammes, L. F. & Sons, Inc. (A, B, F)
Greene, G. G. Corp. (F)
Hayden Wire Works, Inc. (F)
Hodges, William & Co., Inc. (F)
Hunter Spring Co. (F)
Industrial Precision Products (A, B, C, D, E, F, G, H)
Irvington Form & Tank Corp. (F)
Judd Industries, Inc. (A, F)
King Laboratories, Inc. (A, E, F)
Larkin Specialty Mfg. Co. (A, B, E, F)
Leach & Garner Co., Industrial Div. (A, B, E)
Melco Wire Products (A)
Metal Textile Corp. (A, B, E, F)
Michigan Wire Cloth Co. (A, B, E, F)
Mid-West Wire Products Co., Inc. (F)
Morse, Fred W. Co. (A, B, F)
Mutual Screw & Supply Corp. (A, B, C, F)
Newark Wire Cloth Co,
Ormond Mfg. Co., Inc. (A, B, C, E, F, H)
Parker Metal Goods Co. (A, B, C, F)
Penrod, Floyd & Sons Tool & Engineering Corp. (F)
Pittsburgh Steel Co. (F)
Reliable Spring & Wire Forms Co. (A, B, E, F)
Republic Steel Corp. (F)
Reynolds Wire Div., National-Standard Co. (A, B, E, F)
Riverside-Alloy Metal Div., H. K. Porter Co., Inc. (B, E, F)
Robertson Steel & Iron Co. (A, B, F)
Rockford Bolt & Steel Co. (F)
Roebling's Sons, John A. (F)
Rolock, Inc. (E)
Serwell Products Co. (F)
Simonsen Metal Products Co. (A, B, F)
Steel Heddle Mfg. Co. (A, B, C, D, E, F)
Titchener, E. H. & Co. (A, B, E, F)
Turner & Seymour Mfg. Co. (A, B, F)
Wal-Mar Corp. (A, B, C, F)
Ward, H. H. Co. (A, B, C, E, F, H)
Waterbury Buckle Co. (A, B, F)
Wesco Spring Co. (A, B, F)
Whyte, Oliver Co., Inc. (F)
Wilder Mfg. Co., Inc. (A, B, F)
Wire and Iron Products, Inc. (A, B, C, E, F)
Wood, John Co. (F)
Worth Co. (A, B, D, F)

WOOD AND WOOD-BASE MATERIALS (see also Cork and Paper)

American Box Co.
American Parboard Corp.
American Plywood Div., Curtis Co., Inc.
Artyle Industries, Inc.
Balsa Ecuador Lumber Corp.
Binswanger & Co.
Bishop & Watrous Novelty Works
Boos, John & Co.
Brewer-Titchener Corp.
Cavalier Corp.
Coated Abrasive Products, Inc.
Darlington Veneer Co., Inc.
Delta Plywood Corp.
Evans Products Co.
Fibron Products Inc.
Forest Fiber Products Co.
Gamble Bros., Inc.
Georgia-Pacific Corp.
Haskelite Mfg. Corp.
International Balsa Corp.
International Paper Co., Long-Bell Div.
Kipp & Co., Inc.
Lignum-Vitae Products Corp.
Lumb Woodworking Co., Inc.
Martin Bros. Container & Timber Products Corp.
Masonite Corp.
Mengel Co.
Met-L-Wood Corp.
Midwest Mfg. Co.

Monteath, J. H. Co.
National Starch Products, Inc.
Nu-Ply Corp.
Penn Veneer Co., Inc.
Pilgrim Plywood Corp.
Puget Sound Plywood, Inc.
Roddis Plywood Corp.
Tiffin Enterprise, Inc.
Timber Products Co.
U.S. Gypsum Co.
U.S. Plywood Corp.
Wabash Screen Door Co.

WOOL FELTS (see Felts)

WROUGHT IRON (see Iron)

ZINC AND ITS ALLOYS

Alpha Metals, Inc. (7)
American Zinc Sales Co. (1, 2, 3, 8, 9)
Apex Smelting Co. (8)
Belmont Smelting & Refining Works, Inc. (1, 2, 8, 10, 13)
Bunker Hill Co., Sales & Fabrication Div. (1, 2, 13)
Chicago Smelting & Refining Corp. (8)
Crown Non-Ferrous Foundry, Inc. (8)
Duane Specialties, Ltd. (8)
Eagle-Picher Co. (3, 10)
Federated Metals Div., American Smelting and Refining Co. (1, 2, 3, 8)
Fox Products Co. (1)
Hardy, Charles Inc. (10)
Hodgson Foundry Co. (1)
Jordan Co. (8)
Illinois Smelting & Refining Co. (2, 5, 8, 9, 10, 12, 13, 14)
Illinois Zinc Co., Div. of Hydrometals, Inc. (8, 9, 12, 13, 14)
Kirk, Morris P. & Son, Inc. (1)
Lavin, R. and Sons, Inc. (1, 8)
Matthiessen & Hegeler Zinc Co. (1, 2, 3, 7, 8, 9, 10, 12, 13, 14)
McGean Chemical Co. (1)
Metals Disintegrating Co. (10)
New England Smelting Works, Inc. (2, 8)
New Jersey Metals Co. (1)
New Jersey Zinc Co. (1, 8, 10, 11, 14)
Niagara Falls Smelting & Refining Div, Continental Copper & Steel Industries Inc. (7, 8)
Peerless Alloy Co. (2, 8)
Pittsburgh Smelting & Refining Co. (8)
Republic Metals Co., Inc. (2, 8, 9)
St. Joseph Lead Co. (9)
U.S. Reduction Co. (8)
U.S. Smelting, Refining and Mining Co. (8)
Wall Colmonoy Corp. (10)

ZIRCONIUM AND ITS ALLOYS

American Silver Co., Inc. (7, 14)
Belmont Smelting & Refining Works, Inc. (8, 10)
Bridgeport Brass Co. (12)
Carborundum Metals Co., Div. of Carborundum Co. (2, 3, 8, 9, 10, 12, 13, 14)
Chase Brass & Copper Co. (2, 12)
Columbia National Corp. (8)
Firth Sterling Inc. (2, 3, 8, 12, 14)
Foote Mineral Co. (2, 7, 13)
General Plate Div., Metals & Controls Corp. (7, 14)
Hardy, Charles Inc. (10)
Harvey Aluminum Div., Harvey Machine Co., Inc. (2, 3, 8, 12)
King Laboratories, Inc. (10)
Metal Hydrides Inc. (8, 10)
Niagara Falls Smelting & Refining Div., Continental Copper & Steel Industries Inc. (8)
Superior Steel Corp. (14)
U.S. Industrial Chemicals Co., Div. National Distillers & Chemical Corp. (8)

Addresses of Suppliers

a

ACF Industries, Inc., American Car & Foundry Div., 30 Church St., New York 8, N. Y.
AGP Corp., 320 W Main, Peru, Ind.
aaRBee Plastic Co., 4505 W Jefferson Blvd., Los Angeles 16, Calif.
Abco Aluminum & Brass Works, 5235 Griggs Rd., Houston 21, Tex.
Abegg & Reinhold Co., 2533 E 26th St., Los Angeles 58, Calif.
Able Tool & Engineering Co., 865 N Sangamon St., Chicago 22, Ill.
Accurate Brass Co., Inc., 88th St. & 73rd Ave., Glendale, L. I., N. Y.
Accurate Metal Weather Strip Co., Inc., 725 S Fulton Ave, Mt. Vernon, N. Y.
Accurate Sheet Metal & Mfg. Works, 2336 N Milwaukee Ave., Chicago 47, Ill.
Ace Metal Spinning, 4922-24 S Western Ave., Chicago 9, Ill.
Ace Plastic Co., 91-30 Van Wyck Expy., Jamaica 35, N. Y.
Ace Wire Spring & Form Co., Inc., Tunnel Way, McKees Rocks, Pa.
Acme Aluminum Foundry Co., 6831 S Bell Ave., Chicago, Ill.
Acme Foundry & Machine Co., 400 E Frisco, Blackwell, Okla.
Acme Mfg. & Gasket Co., 738-40 N 41st St., Philadelphia 4, Pa.
Acme Metal Spinning, Inc., 98 43rd Ave. NE, Minneapolis 21, Minn.
Acme-Newport Steel Co., 9th & Lowell Sts., Newport, Ky.
Acme Plating Co., 1563 E 21st St., Cleveland 14, Ohio
Acme Precision Products, Inc., 215 N Findlay St., Dayton 3, Ohio
Acme Resin Corp., 1401 Circle Ave., Forest Park, Ill.
Acme Specialties, Inc., 4326 N American St., Philadelphia 40, Pa.
Acme Stamping & Mfg. Co., 201-209 Corliss St., Pittsburgh 20, Pa.
Acme Steel & Malleable Iron Works, Buffalo 7, N. Y.
Acorn Refining Co., 8001 Franklin Blvd., Cleveland 2, Ohio
Acorn Sheet Metal Mfg. Co., Inc., 4605 W 21st St., Chicago 50, Ill.
Acro Metal Stamping Co., 332 E Reservoir, Milwaukee 12, Wis.
Acushnet Process Co., Belleville Ave., New Bedford, Mass. (Ad p 183)
Adamas Carbide Corp., Market & Passaic Sts., Kenilworth, N. J.
Adams, S. G. Metalware Co., 2947 Delmar Pl., St. Louis, Mo.
Adams Plastic Products, Finlay & Providence Sts., Cincinnati, Ohio
Adcraft Mfg. Co., 455-57 N Oakley Blvd., Chicago 12, Ill.
Adelphi Paint & Color Works, Inc., 86-00 Dumont Ave., Ozone Park 17, N. Y.
Adhesive Products Corp., 1616 Boone Ave., New York 60, N. Y.
Adirondack Foundries & Steel, Inc., Watervliet, N. Y.
Admiral Corp., Molded Products Div., P. O. Box 338, West Chicago, Ill.

Addresses of Suppliers

Advance Aluminum Casting Corp., 2742 W 36th Pl., Chicago 32, Ill.
Advance Foundry Co., 107 Seminary Ave., Dayton 3, Ohio (Ad p 356)
Advance Tool & Die Casting Co., 3760-3782 N Holton St., Milwaukee 12, Wis.
Aelco Brass Foundry, 1980 S 4th St., Milwaukee 4, Wis.
Aero Screw Co., Inc., Wilmington Rd., Burlington, Wis.
Aerolite Electronics Corp., 507 26th St., Union City, N. J.
Aerovox Corp., Crowley Div., 1 Central Ave., West Orange, N. J.
Aetna Felt Co., 204 Centre St., New York, N. Y.
Aetna Steel Co., P. O. Box 2090, Jacksonville 3, Fla.
Air Reduction Co., Inc., Colton Chemical Co. Div., 1747 Chester Ave., Cleveland 14, Ohio
Air Reduction Sales Div., 60 E 42nd St., New York, N. Y.
Aircraft Screw Machine Products Co., 3521 N Halsted St., Chicago 13, Ill.
Akron Standard Molded Co., Lectromelt Casting Div., Houston St., Barberton, Ohio
Alabama Wire Co., Inc., P. O. Box 562, Florence, Ala.
Aladdin Products Co., 26-04 Borough Pl., Woodside 77, N. Y.
Alan Wood Steel Co., Wood Rd., Conshohocken, Pa.
Albany Car Wheel Co., Inc., 185 Broadway, Menends, N. Y.
Albany Novelty Mfg. Co., 107 W Canton St., Boston 18, Mass.
Albert Lea Foundry Co., 910 Marshall Ave., Albert Lea, Minn.
Albert Pipe Supply Co., Inc., 8 Berry St., Brooklyn 11, N. Y.
Albi Mfg. Co., Inc., 98 E Main St., Rockville, Conn.
Albion Malleable Iron Co., Albion, Mich.
Albright Son & Co., 123 N Front St., Allentown, Pa.
Alcasco Foundry, 14823 Loomis, Harvey, Ill.
Alco Products, Inc., 30 Church St., New York, N. Y.
Thermal Products Div., Dunkirk, N. Y.
Alexander Bros. Belting Co., Walnut St. & Princess Ave., Camden 3, N. J.
Alexander, E. P. & Son, Clifton Heights, Pa.
All Plastics Corp., Field & Main, Avon-by-the-Sea, N. J.
Allegheny Foundry Co., 915 Behan St., Pittsburgh 33, Pa.
Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa. (Ad p 73)
Allegheny Plastics, Inc., Rt. 51 & Thorn Run Rd., Coraopolis, Pa.
All-Form Metal Products Co., 13000 Athens Ave., Cleveland 7, Ohio
Allianceware, Inc., P. O. Box 809, Alliance, Ohio
Allied Chemical & Dye Corp.; 61 Broadway, New York 6, N. Y.
Barrett Div., 40 Rector St., New York 6, N. Y.
General Chemical Div., 40 Rector St., New York 6, N. Y.
Allied Machine Products Co., 6174 Concord Ave., Detroit 11, Mich.
Allied Products Corp., Powdered Metal Parts Div., 456 E Cady St., Northville, Mich.
Allied Research Products Inc., 4004 E Monument St., Baltimore 5, Md. (Ad p 273)
Allied Steel Castings Co., 1225 W 120th St., Chicago 43, Ill.
Allied Tube Corp., Bristol & Bath Sts., Philadelphia 37, Pa.
Allis-Chalmers Mfg. Co., 501 N 3rd St., LaCrosse, Wis.
Allmetal Screw Products Co., Inc., 821 Stewart Ave., Garden City, N. Y.
All-Metals Precision Casting Corp., 26 School St., Yonkers 2, N. Y.
Alloy Cast Steel Co., Rose Ave., Marion, Ohio
Alloy Metal Powders, Inc., 238 Eagle St., Brooklyn, N. Y.
Alloy Metal Products, Inc., Rockingham Rd., Davenport, Iowa
Alloy Metal Wire Co., Inc., Moore Station, Prospect Park, Pa.
Alloy Precision Castings Co. 3885 W 150th St., Cleveland 11, Ohio (Ad p 312)
Alloy Products Corp., 1045 Perkins Ave., Waukesha, Wis.
Alloy Rods Co., York 7, Pa.
Alloy Steel Casting Co., Southampton, Pa.
Alloy Steel & Metals Co., 1848 E 55th St., Los Angeles 58, Calif.
Alloy Surfaces Co., 100 Justison St., Wilmington 99, Del.
Alloys & Chemicals Mfg. Co., 4365 Bradley Rd. SW, Cleveland 9, Ohio
All-State Welding Alloys Co., Inc., 249 Ferris Ave., White Plains, N. Y.
Almco Steel Products Corp., Wabash Ave., Bluffton, Ind.
Almont Mfg. Co., 335 E 3rd St., Imlay City, Mich.
Alofs Mfg. Co., 345 32nd St. SW, Grand Rapids 8, Mich.
Alox Mfg. Co., 6160 Maple Ave., St. Louis 14, Mo.
Alpha Metals, Inc., 56 Water St., Jersey City 4, N. J.
Alphaloy Div., 2250 S Lumber St., Chicago, Ill.
Alpha Molykote Corp., 65 Harvard Ave., Stamford, Conn.
Alpha Products, Inc., 6825 S Chicago Ave., Chicago 37, Ill.
Alpha Wire Corp., 190-200 Varick St., New York 14, N. Y.
Alsynite Co. of America, 4654 DeSoto St., San Diego 9, Calif.
Aluminium Ltd. Sales, Inc., 630 5th Ave., New York 20, N. Y.
Aluminum Casting & Engineering Co., 2039 S Lenox St., Milwaukee 7, Wis.
Aluminum Co. of America, 1501 Alcoa Bldg., Pittsburgh 19, Pa. (Ad p 339)
Aluminum Extrusions, Inc., 815 Shepherd St., Charlotte, Mich.
Aluminum Finishing Corp., 1012 E 21st St., Indianapolis 2, Ind.
Aluminum Foils, Inc., P. O. Box 540, Jackson, Tenn.
Aluminum Goods Mfg. Co., Manitowoc, Wis.
Aluminum Industries, Inc., 3670 Werk Rd., Cincinnati 11, Ohio
Aluminum & Magnesium, Inc., 1 Huron St., Sandusky, Ohio
Aluminum Permanent Mold Co., 1054 Front Ave. NW, Grand Rapids 4, Mich. (Ad p 356)
Aluminum Smelting & Refining Co., Bedford, Ohio
Aluminum Specialty Co., 17th & Wollmer Sts., Manitowoc, Wis.
Amalgamated Steel Corp., 7835 Broadway Ave., Cleveland 5, Ohio
Ambassador Plastics & Mfg. Corp., 308 W Erie, Chicago 10, Ill.
Amco Plastic Pipe Co., 2002 Davis St., San Leandro, Calif.
Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.
American Agile Corp., 5461 Dunham Rd., Maple Heights, Ohio
American Aluminum Casting Co., 324 Colt St., Irvington 11, N. J.
American Asbestos Textile Corp., Stabridge & Sterigere Sts., Norristown, Pa.
American Box Co., 1900 W 3rd St., Cleveland 13, Ohio
American Brake Shoe Co., 530 5th Ave., New York 36, N. Y. (Ad p 351)
American Manganese Steel Div., 388 E 14th St., Chicago Heights, Ill.
Amforge Div., 155 N Wacker Dr., Chicago 30, Ill.
Brake Shoe & Castings Div., 230 Park Ave., New York, N. Y.
Electro-Alloys Div., Taylor St. & Abbe Rd., Elyria, Ohio
National Bearing Div., 4930 Manchester Ave., St. Louis, Mo.
American Brass Co., 25 Broadway, New York 4, N. Y. (Ads pp 112, 311)
American Metal Hose Div., 698 S Main St., Waterbury 20, Conn.
American Cast Iron Pipe Co., 2930 16th St. N, Birmingham 4, Ala. (Ad p 310)
American Chain & Cable Co., Inc., Reading, Pa.
American Chemical Paint Co., Ambler, Pa. (Ad p 264)
American Crucible Products Co., 1305 Oberlin Ave., Lorain, Ohio
American Cynamid Co., Plastics & Resins Div., 30 Rockefeller Plaza, New York 20, N. Y.
American Electric Cable Co., 181 Appleton St., Holyoke, Mass.
American Electrical Products Co., P. O. Box 200, 653 Lida St., Mansfield, Ohio
American Emblem Co., Inc., P. O. Box 116, Utica 1, N. Y.
American Fabricated Products Co., 1420 E 20th St., Indianapolis 7, Ind.
American Felt Co., Glenville, Conn. (Ad p 245)
American Foundries Co., 330 2nd St., Milan, Mich.
American Foundry Co., Inc., 1100 S Tibbs Ave., Indianapolis 21, Ind.
American Hard Rubber Co., 93 Worth St., New York 13, N. Y. (Ad pp 198, 199)
Supplex Co. Div., 225 North Ave., Garwood, N. J.
American Insulator Corp., New Freedom, Pa. (Ad p 324)
American Kleer-Vu Plastics, Inc., 53-06 Grand Ave., Maspeth 78, N. Y.
American Latex Products Corp., 3341 W El Segundo Blvd., Hawthorne, Calif.
American Laundry Machinery Co., Rochester, N. Y.
American Lava Corp., Cherokee Blvd. & Manufacturers Rd., Chattanooga 5, Tenn.
American Light Alloys, Inc., 1265 McBride Ave., Little Falls, N. J.
American Luminous Products Co., 6420 Marbrisa Ave., Huntington Park, Calif.
American Machine & Foundry Co., Cleveland Welding Div., W 17th & Berea Rd., Cleveland 11, Ohio (Ad p 349)
American Malleable Castings Co., Marion, Ohio
American Manganese Bronze Co., Rhawn & Torresdale Aves., Philadelphia 36, Pa.
American Mfg. Co., 124 Chestnut, Chattanooga 2, Tenn.
American Metal Co., Ltd., 61 Broadway, New York 6, N. Y. (Ad pp 114, 115)
American Metal Products Co., Linsdale Ave., Detroit 4, Mich.
American Metal Products, Inc., 4500 W Mitchell Ave., Cincinnati 32, Ohio
American Molding Co., 2002 Davis St., San Leandro, Calif.
American Molding Powder & Chemical Co., 703 Bedford Ave., Brooklyn 8, N. Y.
American Nickel Alloy Mfg. Corp., 30 Vesey St., New York 7, N. Y.
American Nickeloid Co., 2nd & West Sts., Peru, Ind.

American Parboard Corp., Black Moutain, N. C.
American Pipe & Construction Co., 518 NE Columbia Blvd., Portland 11, Ore.
American Plastics Corp., 342 Madison Ave., New York 17, N. Y.
American Platinum Works, Newark 5, N. J.
American Potash & Chemical Co., 122 E 42nd St., New York, N. Y.
American Powdered Metals, Inc., North Haven, Conn.
American Products Mfg. Co., Inc., 8127-33 Oleander St., New Orleans 18, La.
American Reed Co., Inc., 2 S Broadway, Lawrence, Mass.
American Reinforced Plastics Co., 12827 E Imperial Hwy., Norwalk, Conn.
American Rubber Products Corp., 315 Brighton, LaPorte, Ind.
American Sand-Banum Co., Inc., Meadow Brook National Bank Bldg., Freeport, N. Y.
American Sanitary Mfg. Co., 499 Latimer, Abington, Ill.
American Screw Products Co., 5943 Martin Ave., P. O. Box 96, Detroit 10, Mich.
American Sheet Metal Works, Inc., 16 Jefferson St., Waterbury 20, Conn.
American Silver Co., Inc., 36-07 Prince St., Flushing 54, N. Y.
American Sinteel Corp., 318 Yonkers Ave., Yonkers 2, N. Y.
American Smelting & Refining Co., Barber, N. J.
Federated Metals Div., 120 Broadway, New York 5, N. Y. (Ads pp 117, 118, 119, 120, 132, 270, 350, 426)
American Solder & Flux Co., 19th & Willard Sts., Philadelphia 40, Pa.
American Stamping Co., 26650 Lakeland Blvd., Cleveland 32, Ohio
American Standard Co., Youngstown Kitchens Div., Ellsworth Ave., Salem, Ohio
American Steel Foundries, Prudential Plaza, Chicago 1, Ill.
American Steel & Pump Corp., Oklahoma Steel Castings Div., 1200 N Peoria Ave., Tulsa, Okla.
American Synthetic Rubber Corp., 500 5th Ave., New York 36, N. Y.
American Valve & Enameling Corp., 2855 S Holt Rd., Indianapolis 21, Ind.
American Viscose Corp., Film Div., 1617 Pennsylvania Blvd., Philadelphia 3, Pa. (Ad p 243)
American Welding & Mfg. Co., 190 Dietz Rd., Warren, Ohio
American Zinc Sales Co., 1522 Paul Brown Bldg., St. Louis 1, Mo.
Amersil Co., Inc., 686 Ramsey Ave., Hillside 5, N. J.
Ames, W. & Co., 417 Communipaw Ave., Jersey City 4, N. J.
Amos-Thompson Corp., Amos Molded Plastics Div., Edinburg, Ind. (Ad p 337)
Ampco Metal, Inc., 1753 S 38th St., Milwaukee 46, Wis.
Anaconda Aluminum Co., 25 Broadway, New York 4, N. Y.
Anchor Metal Co., Inc., 966 Meeker Ave., Brooklyn 22, N. Y.
Anchor Metal Spinning, 46 Fluhart Ave., Dayton, Ohio
Anchor Plastics Co., 36-36 36th St., Long Island City 6, N. Y. (Ad p 338)
Anderson Associates, Inc., 1702 Wayne St., P. O. Box 674, Toledo 1, Ohio
Anderson-Bolling Mfg. Co., Grand Haven, Mich.
Anderson, O. L. Co., Inc., 1347 E Fort St., Detroit 7, Mich.
Anesite Co., 3575 Touhy Ave., Chicago 45, Ill.
Anthes Force Oiler Co., 20th St. & Ave. M, Fort Madison, Iowa
Anti-Corrosive Metal Products Co., Inc., Castleton-on-Hudson, N. Y.
Apex Foundry Inc., 633 Lycaste Ave., Detroit 14, Mich.
Apex Smelting Co., 2537 W Taylor St., Chicago 12, Ill.
Apex Steel Corp. Ltd., 6920 E Slauson, Los Angeles 22, Calif.
Apollo Metal Works, 6678 S Oak Park Ave., Chicago 38, Ill.
Appleton Electric Co., 1701 W Wellington Ave., Chicago 13, Ill.
Applied Instruments, Inc., 25 Will Pl., Brooklyn 7, N. Y.
Approved Mfg. Co., Inc., 307990 W 8th Mile Rd., Farmington, Mich.
Arbonite Corp., 900 N Main St., Doylestown, Pa.
Archer-Daniels-Midland Co., 700 Investors Bldg., Minneapolis, Minn.
Arcos Corp., 1502 S 50th St., Philadelphia, Pa.
Ar-Dee Screw Products Co., Inc., 1885 N Clybourn Ave., Worcester 5, Mass.
Argosy Products, Inc., 7504 Carnegie Ave., Cleveland 3, Ohio
Arkansas Foundry Co., 1423 E 6th St., Box 231, Little Rock, Ark.
Armco Steel Corp., 703 Curtis St., Middletown, Ohio
Sheffield Div., Sheffield Station, Kansas City 25, Mo.
Armet Alloys Inc., Box 3562, Cleveland 18, Ohio
Armitage, John L. & Co., 245 Thomas St., Newark, N. J.
Armor Metal Products Co., 3408 Beekman, Cincinnati 23, Ohio
Armstrong Cork Co., W Liberty St., Lancaster, Pa.
Armstrong Products Co., P. O. Box 1-MM, Warsaw, Ind.
Arneson Foundry, Inc., 3303 66th St., Kenosha, Wis.
Arnold Engineering Co., P. O. Box G, Marengo, Ill.
Arrow Sintered Products Co., 1900 S Kostner Ave., Chicago, Ill.
Arrowhead Products, 2300 Curry St., Long Beach 5, Calif.
Art Wire & Stamping Co., 227 High St., Newark 2, N. J. (Ad p 324)
Artex Felt Co., 62 W 39th St., New York 18, N. Y.
Artmor Plastics Corp., 1003 Oldtown Rd., Cumberland, Md.
Artyle Industries, Inc., Box 28, Eaton, Ohio
Arvin Industries, Columbus, Ohio
Arwood Precision Casting Corp., 321 W 44th St., New York 36, N. Y.
Arzt, T. L. Foundry Co., 4020 W Schubert Ave., Chicago 39, Ill.
Asbestos Corp. of America, 31 North Ave., Garwood, N. J.
Asbestos Textile Co., Inc., 165 W Wacker Dr., Chicago 1, Ill.
Asco Sintering Corp., 7799 Telegraph Rd., Los Angeles, Calif.
Ashby Mfg. Co., 1601 Woodson Rd., St. Louis 11, Mo.
Ashland Oil & Refining Co., Valvoline Co. Div., 3rd Ave., Freedom, Pa.
Ashtabula Mfg. Co., W 30th St., Ashtabula, Ohio
Associated Engineering & Mfg. Corp., Glen Ridge, N. J.
Associated Spring Corp., 18 Main St., Bristol, Conn.
Associated Spring Corp., Milu Div., 341 E Erie, Milwaukee, Wis.
Atech, Inc., 3839 Pitt St., Toledo 12, Ohio
Athenia Steel Co., Clifton Ave., Clifton, N. J.
Atlanta Tool Co., Inc., 670 Boulevard NE, Atlanta 5, Ohio
Atlantic Bag Co., 435 S 5th St., Brooklyn 11, N. Y.
Atlantic Brass Works, Inc., 2600 W Addison St., Chicago 18, Ill.
Atlantic Casting & Engineering Corp., 810 Bloomfield Ave., Clifton, N. J.
Atlantic Foundry Co., 182 Beaver St., Akron 4, Ohio
Atlantic Steel Casting Co., 6th & Lloyd Sts., Chester, Pa.
Atlas Brass Foundry, 1901 Santa Fe Ave., Los Angeles 21, Calif.
Atlas Enameling Co., Inc., 2020 N Broadway, St. Louis, Mo.
Atlas Foundry Co., 3600 W 69th St., Cleveland 2, Ohio
Atlas Foundry Co., 131 S Livernois Ave., Detroit, Mich.
Atlas Foundry & Machine Co., 3012 S Wilkeson St., Tacoma, Wash.
Atlas Mineral Products Co., Mertztown, Pa.
Atlas Powder Co., Wilmington 99, Del.
Atlas Steel Construction Co., 20 Vesey St., New York 7, N. Y.
Auburn Foundry Inc., W 11th St., Auburn, Ind.
Auburn Mfg. Co., 20 Stack St., Middletown, Conn. (Ad p 332)
Auburn Plastic Engineering, 742 W 79th St., Chicago 20, Ill.
Auburn Plastics, Inc., 48 Canoga St., Auburn, N. Y.
Auburn Rubber Co., Inc., W 11th St., Auburn, Ind.
Auburn Spark Plug Co., Inc., 89 York St., Auburn, N. Y.
Auel Industries, Herminie, Pa.
Auld, D. L. Co., 5th Ave. & 5th St., Columbus, Ohio
Aurora Metal Co., 614 W Park Ave., Aurora, Ill.
Aurora Refining Co., P. O. Box 88, Aurora, Ill.
Austenal, Inc., 224 E 39th St., New York 19, N. Y. (Ad p 317)
Autel Electronics Co., Precision Machine & Welding Div., 1122 E St. George Ave., Linden, N. J.
Auto Glass Mfg. Co., 8701 Grinnell Ave., Detroit 13, Mich.
Auto Specialties Mfg. Co., 643 Graves St., St. Joseph, Mich.
Automatic Metal Products Corp., 315-323 Berry St., Brooklyn 11, N. Y.
Automotive Rubber Co., Inc., 12550 Beech Rd., Detroit 28, Mich.
Avco Mfg. Corp., 420 Lexington Ave., New York, N. Y.
American Kitchens Div., 18th & Columbia, Connersville, Ind.
Avondale Co., 260 Happ Rd., Northfield, Ill.
Avril, G. A. Co., Este Ave. & B & O R. R., Cincinnati, Ohio

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B G Corp., 321 Broad Ave., Ridgefield, N. J.
B & T Metals Co., 425 Town St., Columbus 16, Ohio
Babbitt Chemical Co., 36 Prospect, New Bedford, Mass.
Babcock & Wilcox Co., Tubular Products Div., Beaver Falls, Pa. (Ad p 345)
Babson-Dow Mfg. Co., 60 Fulda St., Roxbury 19, Mass.
Backus Novelty Co., 411 Water St., Smethport, Pa.

Addresses of Suppliers

Bacon Felt Co., 427 W Water St., Taunton, Mass.
Badger Automatic Products Corp., 3637 S Ellen St., Milwaukee 7, Wis.
Badger Die Casting Co., 201 W Oklahoma Ave., Milwaukee 7, Wis.
Badger Malleable & Mfg. Co., South Milwaukee, Wis.
Baer, N. S. Co., 1-11 Montgomery St., Hillside, N. J.
Baker & Co., Inc., 113 Astor St., Newark 2, N. J.
Balas Collet Mfg. Co., 1557 E 27th St., Cleveland 14, Ohio
Baldwin-Lima-Hamilton Corp., Standard Steel Works Div., Paschall Station, Philadelphia, Pa.
Baldwin Mfg. Co., 140 Homer St., Waterbury 20, Conn.
Bally Metal Products, Inc., Bally, Pa.
Balsa Ecuador, Lumber Corp., 502 Fifth Ave., New York 36, N. Y.
Bamberger, Claude P. Inc., 1 Mt. Vernon St., Ridgefield Park, N. J.
Banner Iron Works, St. Louis, Mo.
Barclay Mfg. Co., 1013 S Council St., Muncie, Ind.
Barnard Foundry Co., Inc., 9 Roseland St., Springfield 7, Mass.
Barnett Foundry & Machine Co., Irvington, N. J.
Bar-Ray Products, 209 25th St., Brooklyn 32, N. Y.
Barrett Varnish Co., 1532 S 50th Court, Cicero 50, Ill.
Barrows Porcelain Enamel Corp., Langdon Farm Rd. & Penn R.R., Cincinnati 17, Ohio
Bart Mfg. Corp., 227 Main St., Belleville 9, N.J.
Barth Smelting Corp., 99-129 Chapel St., Newark 5, N. J.
Bartlett-Thompson Co., Inc., 26 Water St., Wakefield, Mass.
Barton Products Corp., P. O. Box 305, West Bend, Wis.
Bassichis Co., 2323 W 3rd St., Cleveland 13, Ohio
Bassick Co., Howard Ave., Bridgeport, Conn.
Bassons Industries Corp., 1432 W Farms Rd., Bronx 60, N. Y.
Bausch & Lomb Optical Co., 626 St. Paul St., Rochester 2, N. Y.
Baxter Foundry & Machine Works, Inc., 1501 Capitol Blvd., Boise, Id.
Bay City Electric Steel Casting Co., Trumbell St., Bay City, Mich.
Bay City Forge Co., 1802 Cranberry St., Erie, Pa.
Bay Ridge Specialty Co., Inc., 96 Stokes St., Trenton 7, N. J.
Bay State Refining Co., Inc., 9 Montgomery St., Chicopee Falls, Mass.
Bay State Stamping Co., 372 Chandler St., Worcester, Mass.
Bay State Tool & Machine Co., 412 Albany, Springfield 4, Mass.
Bayley Products, Inc., 19155 Glendale Ave., Detroit 5, Mich.
Beacon Metal Mfg. Co., 1127 Atlantic Ave., Brooklyn 16, N. Y.
Bean, Morris & Co., Hyde Rd., Yellow Springs, Ohio
Beatty Machine & Mfg. Co., 940 150th St., Hammond, Ind.
Beaver Valley Alloy Foundry Co., Atlantic Ave., Monaca, Pa.
Beck Products Corp., 12255 E 8th Mile Rd., Detroit 5, Mich.
Beck, I. & Sons, Inc., 256 Mott St., New York 12, N. Y.
Beckmann, Inc., 42 W 38th St., New York 18, N. Y.
Bee Chemical Co., 12907 S Stony Island Ave., Chicago, Ill.
Behringer Metal Works, Inc., 108 Jabez St., Newark 5, N. J.
Belcher Malleable Iron Co., 558 Foundry St., Eaton, Mass.
Belding Corticelli Industries, 1407 Broadway, New York 18, N. Y.
Belko Corp., Kingsville, Md.
Bell, David Co., Inc., 1555 Fillmore Ave., Buffalo 11, N. Y.
Belle City Malleable Iron Co., 1442 Forest St., Racine, Wis.
Belmet Products, Inc., 503 Morgan Ave., Brooklyn 22, N. Y.
Belmont Aluminum Extrusion Co., 1228 Belmont Ave., Philadelphia 4, Pa.
Belmont Smelting & Refining Works, Inc., 330 Belmont Ave., Brooklyn 7, N. Y.
Beloit Iron Works, Rock River, Beloit, Wis.
Benada Aluminum Products Co., 37 James St., Girard, Ohio
Bendix Aviation Corp., Teterboro, N. J. (Ad p 331)
Benjamin Electric Mfg. Corp., Northwest Hwy., Des Plaines, Ill.
Bennett Mfg. Co., 41 Mechanic, Alden, N. Y.
Bergen Point Iron Works, 233 Broadway, New York 7, N. Y.
Bergfeld, William & Co., 10 Orchard St., Newark 2, N. J.
Beryl Ores Co., Kettner & Alkite, Arvada, Colo.
Beryllium Corp., Tuckerton Rd., Reading, Pa (Ad pp 139, 140)
Bethandale Corp., 24040 Lakeland Blvd., Cleveland 23, Ohio
Bethlehem Steel Co., 701 3rd St., Bethlehem, Pa.
Better Finishes & Coatings Inc., 270 Doremus Ave., Newark, N. J.
Bettinger Corp., Gore St., Waltham, Mass.
Bickford, F. H. Co., 1529 S Broadway, Dayton 8, Ohio
Biddle Screw Products Co., P. O. Box 71, Sheridan, Ind.
Biersach & Niedermeyer Co., 1936 N Hubbard St., Milwaukee, Wis.
Biggs, Carl H. Co., Inc., 2255 Barry Ave., Los Angeles 64, Calif.
Billings & Spencer Co., 1 Laurel St., Hartford 1, Conn.
Binswanger & Co., 3300 W Leigh St., Richmond, Va.
Bio-Rad Laboratories, 800 Delaware St., Delaware, Calif.
Birdsboro Steel Foundry & Machine Co., Birdsboro, Pa.
Bischoff Chemical Corp., 120 Main, Ivoryton, Conn.
Bishop, J. & Co., Platinum Works, Malvern, Pa. (Ad p 330)
Bishop & Watrous Novelty Works, Chester, Conn.
Bishopric Products Co., 4413 Este Ave., Cincinnati 32, Ohio
Bisonite Co., P. O. Box 84, Kenmore Station, Buffalo 17, N. Y.
Blacher Bros. Inc., 299 Carpenter St., Providence 9, R. I.
Black Bear Co., Inc., 44-45 23rd St., Long Island City 1, N. Y.
Black-Clawson Co., Keuthan Foundry Div., 1700 Grand Ave., Middletown, Ohio
Blackmer Pump Co., Dover, Ohio
Blackmer Pump Co., 1809 Century Ave. SW, Grand Rapids, Mich.
Blaco Mfg. Co., 6541 Euclid Ave., Cleveland 8, Ohio
Blakeslee Forging Co., Plant Pl., Plantsville, Conn.
Blank, Arthur & Co., Inc., 38 Causeway St., Boston 14, Mass.
Blaw Knox Co., Pittsburgh, Pa.
Bliss, E. W. Co., Mackintosh-Hemphill Div., 901 Bingham St., Pittsburgh, Pa.
Bliss & Laughlin, Inc., 281 E 155th St., Harvey, Ill.
Blossom Mfg. Co., Inc., 292 5th Ave., New York 1, N. Y.
Boatright Paint & Varnish Works, Inc., P. O. Box 306, Norcross, Ga.
Boehm Screw Products Co., 7114 W Jefferson, Detroit 17, Mich.
Bohn Aluminum & Brass Corp., 1400 Lafayette Bldg., Detroit 26, Mich.
Bond, Charles & Co., 617 Arch St., Philadelphia 6, Pa.
Bond International, Inc., 783 S Deacon, Detroit 17, Mich.
Bone Engineering Corp., 701 W Broadway, Glendale 4, Calif.
Bonney-Floyd Co., 611 Marion Rd., Columbus 7, Ohio
Bonnot Co., 722 Mulberry Rd. SE, Canton 2, Ohio
Booker & Wallstad, Inc., 3336 Gorham Ave., Minneapolis 26, Minn.
Boonton Molding Co., 326 Myrtle Ave., Boonton, N. J.
Boos, John & Co., 1st & National Sts., Effingham, Ill.
Booty Resineers, Inc., 42 S 3rd St., Newark, Ohio
Borden Co., Chemical Div., 350 Madison Ave., New York 17, N. Y.
Borg-Warner Corp., 310 S Michigan Ave., Chicago, Ill.
Franklin Steel Div., Franklin, Pa.
Ingersoll Products Div., 1000 W 120th St., Chicago 43, Ill.
Marbon Chemical Div., 7165 Chicago Ave., Gary, Ind.
Boruski, Ernest F. Jr., 505 5th Ave., New York 17, N. Y.
Boston Felt Co., 210 South St., Boston 11, Mass.
Boston Gear Works, 14 Hayward St., Quincy 71, Mass.
Boston Metals Co., Baldt Anchor, Chain & Forge Div., 6th & Butler Sts., Chester, Pa.
Both, O. A. Corp., Nickerson Rd., Ashland, Mass.
Bound Brook Oil-Less Bearing Co., Bound Brook, N. J.
Bowling Green Rubber Co., 4143 Monroe St., Toledo 13, Ohio
Bradley Mining Co., 660 Market St., San Francisco 4, Calif.
Bradley Paint Co., 609 W Crawford Ave., Connellsville, Pa.
Bradley & Vrooman Co., 2629 S Dearborn St., Chicago 16, Ill.
Brandt, Charles T., Inc., 1700 Ridgely St., Baltimore 30, Md.
Brasco Mfg. Co., Harvey, Ill.
Brewer-Titchener Corp., 111 Port Watson St., Cortland, N. Y.
Bridgeport Brass Co., 30 Grand St., Bridgeport 2, Conn.
Hunter-Douglas Aluminum Div., 3016 Kansas Ave., Riverside, Calif.
Bridgeport Rolling Mills Co., P. O. Box 818, Bridgeport 1, Conn.
Briggs-Shaffner Co., 500 Brookstown Ave., Winston-Salem, N. C.
Brinkerhoff Brass & Bronze Works Inc., 57½ Dey St., New York 7, N. Y.
Bristol Brass Corp., 580 Broad St., Bristol, Conn.
Broadway Mfg. Co., P. O. Box 252, Springdale Rd., Waukesha, Wis.
Brockway Pressed Metals, Inc, 921 Clark St., Brockway, Pa.
Bronze & Steel Die Casting Co., Piano, Ill.
Brooklyn Paint & Varnish Co., Inc., 50 Jay St., Brooklyn, N. Y.
Brooks & Perkins, Inc., 1950 W Fort St., Detroit 16, Mich. (Ad p 316)
Brown Corp., 213 Bellevue Ave., P. O. Box 1374, Syracuse 1, N. Y.
Brown Rubber Co., Inc., P. O. Box 1000, Lafayette, Ind.
Bruce Foundry & Mfg. Co., 4040 S Evans St., Tecumseh, Mich.

Brush Beryllium Co., 4301 Perkins Ave., Cleveland 3, Ohio (Ad p 128)
Buchmann Spark Wheel Corp., 4-20 47th Ave., Long Island City 1, N. Y.
Buckeye Brass & Mfg. Corp., 6410 Hawthorne Ave., Cleveland 3, Ohio
Buckeye Iron & Brass Works, 324 E 3rd St., Dayton 1, Ohio
Buckeye Molding Co., 3rd St., Miamisburg, Ohio
Budd Co., Continental-Diamond Fibre Div., Newark, Del.
Budd-Stanley Co., Inc., 43-01 22nd St., Long Island City 1, N. Y.
Buffalo Wire Works Co, 320 Terrace, Buffalo 2, N. Y.
Bullock, W. J. Inc., P. O. Box 539, Fairfield, Ala.
Bulwark Corp. of America, 9629 E El Poche St., El Monte, Calif.
Bunker Hill Co., 660 Market St., San Francisco 4, Calif.
Bunting Brass & Bronze Co., 715 Spencer St., Toledo 1, Ohio
Detroit Sintered Metals Div., Milgore Rd., Kalamazoo, Mich.
Burgess-Norton Mfg. Co., 737 Peyton St., Geneva, Ill.
Burkhardt Steel Co., 869 S Broadway, Denver 9, Colo.
Burroughs Corp., Plymouth Rd., Plymouth, Mich.
Burwood Products Co., Airport Rd., Traverse City, Mich.
Busada Mfg. Corp., 58-99 54th St., Maspeth 78, N. Y.
Busch, J. C. Co., 17 W 54th St., New York 19, N. Y.
Butler Engine & Foundry Co., Inc., 151 S Monroe, Butler, Pa.
Buttler Mfg. Co., 7309 E 13th St., Kansas City, Mo.
Button Corp. of America, 49 Dickerson St., Newark 9, N. J.
Byers, A. M., 1810 Clark Bldg., Pittsburgh 22, Pa. (Ad p 316)

C

C & G Screw Products Co., P. O. Box 308, Carmel, Ind.
Cadillac Malleable Iron Co., Cadillac, Mich.
Cadillac Plastic & Chemical Co., 15111 2nd Ave., Detroit, Mich.
Calbar Paint & Varnish Co., 2612-26 N Martha St., Philadelphia 25, Pa.
Caldwell, W. E. Co., Inc., 2020 Brook St., Louisville 8, Ky.
Calfibe Co., Inc., P. O. Box 832, Redlands, Calif.
California Drop Forge Co., 1033 Alhambra Ave., Los Angeles 12, Calif.
California Metal Enameling Co., 6904 E Slauson Ave., Los Angeles 22, Calif.
California Perforating Screen Co., 345-347 Folsom St., San Francisco 5, Calif.
Callahan Zinc-Lead Co., Inc., Flexhaust Co. Div., 100 Park Ave., New York 17, N. Y.
Caloric Appliance Corp., Topton, Pa.
Calorizing Co., P. O. Box 8742, Pittsburgh 21, Pa.
Calumet & Hecla, Inc., 1 Calumet Ave., Calumet, Mich.
Wolverine Tube Div., 1439 Central Ave., Detroit 9, Mich.
Calumet Steel Castings Corp., 1636 Summer St., Hammond, Ind.
Cambridge Wire Cloth Co., Cambridge, Md.
Cameron Iron Works, Silber Rd., Houston, Tex.
Campbell, A. S. Co., Inc., 161 Prescott St., East Boston 28, Mass.
Campro Co., 3131 Alliance Rd. NE, Canton 1, Ohio
Cannon-Muskegon Corp., 2875 Lincoln St., Muskegon, Mich.
Capac Industries, Inc., S Main St., Capac, Mich.
Capitol Chemical Co., 4501 W Haddon Ave., Chicago 51, Ill.
Carbo Tool & Die Co., 219 Howland St., Fremont, Ohio
Carboline Co., 331 Thornton Ave., St. Louis 19, Mo.
Carborundum Co., Perth Amboy, N. J.
Refractories Div., Perth Amboy, N. J.
Stupakoff Div., Latrobe, Pa.
Carey, Philip Mfg. Co., Lockland, Cincinnati, Ohio
Carleton Screw Products Co., 2424 Hiawatha Ave. S, Minneapolis 4, Minn.
Carlon Products Corp., 10224 Meech Ave., Cleveland 5, Ohio
Carlson, G. O. Inc., Thorndale, Pa. (Ad p 66)
Carolina Asbestos Co., Davidson, N. C.
Carondelet Foundry Co., 2101 S Kingshighway, St. Louis 10, Mo.
Carpenter Steel Co., 135 W Barn St., Reading, Pa.
Alloy Tube Div., 133 Springfield Rd., Union, N. J. (Ad p 343)
Carroll, J. B. Co., Carroll & Albany Aves., Chicago 12, Ill.
Carroll Pressed Metal Inc., 133 Dewey St., Worcester 10, Mass.
Cartwright, R. Tube Products Co., 609 St. Jean Ave., Detroit 14, Mich.
Cary Chemicals, Inc., 64 Hamilton St., Paterson 1, N. J.
Caspers Tin Plate Co,. 4100 W 42nd Pl., Chicago 32, Ill.
Cast Optics Corp., 123 Newman St., Hackensack, N. J. (Ad p 209)
Casting Engineers, Inc., 2323 N Bosworth, Chicago 14, Ill.
Casting Service Corp. of Michigan, Mathieu Ave., Bridgman, Mich.
Catalin Corp. of America, 1 Park Ave., New York 16, N. Y.
Cavalier Corp., Chattanooga 2, Tenn.
Cayce Corp., 1444 Hamilton Ave., Cleveland 14, Ohio
Cedar Heights Clay Co., 50 Portsmouth Rd., Oak Hill, Ohio
Ceilcote Co., 4832 Ridge Rd., Cleveland 9, Ohio
Celanese Corp. of America, 290 Ferry St., Newark 5, N. J. (Ads pp 191, 192, 193, 194)
Celluplastic Corp., 50 Ave. L, Newark 5, N. J.
Cellusuede Products, Inc., 500 N Madison St., Rockford, Ill.
Central Fabricators Inc., 408-18 Poplar St., Cincinnati, Ohio
Central Felt & Fabrics Corp., 24-26 W 25th St., New York 10, N. Y.
Allied Felt Corp. Div., 46 Starlake Ave., Bloomingdale, N. J.
Central Paint & Varnish Works, Inc., 59-69 Prospect St., Brooklyn 1, N. Y.
Central Screw Products Co., 284 Walker St., Detroit 7, Mich.
Centrifugal Casting Co., 147 W 42nd St., New York 36, N. Y.
Centrifugal Casting Machine Co., P. O. Box 947, Tulsa 1, Okla.
Centr-O-Cast & Engineering Co., 45 St. Jean Ave., Detroit 14, Mich.
Century Vitreous Enamel Co., 6641 S Narragansett Ave., Chicago 38, Ill.
Ceramic Color & Chemical Mfg. Co., 13th St. & Block House Run, New Brighton, Pa.
Cero-Met, 417 W Chestnut, Monrovia, Calif.
Cerro de Pasco Sales Corp., 300 Park Ave., New York 22, N. Y.
Chace, W. M. Co., 1600 Beard Ave., Detroit 9, Mich.
Challenge Stamping & Porcelain Co., Grand Haven, Mich.
Champion Rivet Co., Harvard Ave. & E 108th St., Cleveland 5, Ohio (Ad p 352)
Chapman Machine Co., Inc., 41 Main St., Terryville, Conn.
Chardon Metal Products Co., P. O. Box 67, Washington St., Chardon, Ohio
Chardon Rubber Co., 6th & Washington Aves., Chardon, Ohio
Charlotte Leather Belting Co., 209 E 12th St., Charlotte 1, N. C.
Chase Brass & Copper Co., Inc., 236 Grand St., Waterbury 91, Conn.
Chattanooga Aluminum Foundry, 3126 Alton Park Blvd., Chattanooga, Tenn.
Chemical Corp., 54 Waltham Ave., Springfield 9, Mass. (Ad p 266)
Chemical Process Co., 901 Spring St., Redwood City, Calif.
Chemical Products Corp., King Phillip Rd., Providence 14, R. I.
Chemiglass, Inc., 4670 DeSoto St., San Diego 9, Calif.
Chemung Foundry Corp., Elmira, N. Y.
Chester Packaging Products Corp., 684 Nepperhan Ave., Yonkers 2, N. Y.
Chicago Aluminum Castings, 2647 Ogden Ave., Chicago, Ill.
Chicago Bridge & Iron Co., 322 S Michigan Ave., Chicago 4, Ill.
Chicago Development Corp., 5810 47th Ave., Riverdale, Md.
Chicago Extruded Metals Corp., 1642 S 54th Ave., Cicero 9, Ill.
Harvey Metal Corp. Div., 1605-1725 W 74th St., Chicago 36, Ill.
Chicago Gasket Co., 1271 W North Ave., Chicago 22, Ill.
Chicago Hardware Foundry Co., 2500 Commonwealth Ave. N, Chicago, Ill.
Chicago Malleable Castings Co., 1225 W 120th St., Chicago 43, Ill.
Chicago Molded Products Corp., Campco, Div., 2717 N Normandy, Chicago 35, Ill.
Chicago Paint, Inc., 4500 W 14th St., Chicago 23, Ill.
Chicago Powdered Metal Products Co., 9700 Waveland Ave., Schiller Park, Ill.
Chicago Rawhide Mfg. Co., 1301 Elston Ave., Chicago 22, Ill. (Ad pp 202, 203)
Chicago Rivet Machine Co., 925 S 25th Ave., Bellwood, Ill.
Chicago Rubber Co., Inc., 651 Market St., Waukegan, Ill.
Chicago Screw Co., 2701 Washington Blvd., Bellwood, Ill.
Chicago Smelting & Refining Corp., 3701 S Kedzie Ave., Chicago 32, Ill.
Chicago Thrift-Etching Corp., 1555 N Sheffield Ave., Chicago 22, Ill.
Chicago Vitreous Corp., 1425 S 55th Court, Cicero 50, Ill.
Chicago White Metal Casting Inc., 5239 W Grand Ave., Chicago 39, Ill.
Chicopee Mills, Inc., 49 Worth St., New York, N. Y.
Chippewa Plastics, Inc., 210 W Columbia St., Chippewa Falls, Wis.
Chromalloy Corp., 450 Tarrytown Rd., White Plains, N. Y.
Chrysler Corp., P. O. Box 1687, Detroit 31, Mich.
Amplex Div., 6501 Harper Ave., Detroit 31, Mich.
Ciba Co., Inc., Plastics Div., 627 Greenwich st., New York 14, N. Y.
Cincinnati Forging Co., 5604 Booster Pike, Cincinnati, Ohio
Cincinnati Foundry Co., 238 W Mitchell Ave., Cincinnati 32, Ohio
Cincinnati Pump & Mfg. Co., Inc., 3182 Beekman St., Cincinnati 23, Ohio
City Plating Works, Inc., 905 Honeyspot Rd., Stratford, Conn.
Clad-Rex Corp., 40th & Ulster Sts., Denver 7, Colo.

Addresses of Suppliers

Clapp, E. D. Mfg. Co., 305 Genesee St., Auburn, N. Y.
Claremont Pigment Dispersion Corp., 110 Wallabout St., Brooklyn 11, N. Y.
Clark Bros. Bolt Co., Milldale, Conn.
Clark Gasket Co., 3027 S Wentwork Ave., Chicago 16, Ill.
Clarksville Foundry & Machine Works, Commerce & Spring Sts., Clarksville, Tenn.
Clayton, Mark & Co., 1900 Dempster St., Evanston, Ill.
Clendenin Bros. Inc., 4309 Erdman Ave., Baltimore 13, Md.
Cleveland City Forge Co., 1621 Euclid Ave., Cleveland 15, Ohio
Cleveland Electro Metals Co., 2391 W 38th St., Cleveland 13, Ohio
Cleveland Foundry & Mfg. Co., Inc., 685 6th St. NE, Cleveland, Tenn.
Cleveland Graphite Bronze Co., 17044 St. Clair Ave., Cleveland 10, Ohio
Cleveland Hard Facing Co., Inc., 3047 Stillson Ave., Cleveland 5, Ohio (Ad p 360)
Cleveland Hardware & Forging Co., 3270 E 79th St., Cleveland 4, Ohio
Cleveland Metal Products Co., Washington & Center Sts., Cleveland 13, Ohio
Cleveland Porcelain Enameling Co., 3190 E 65th St., Cleveland 4, Ohio
Cleveland Pressed Products Corp., 6712 Union Ave., Cleveland, Ohio
Cleveland Screw Products Co., 3062 E 93rd St., Cleveland 4, Ohio
Cleveland Steel Specialty Co., 3765 E 91st St., Cleveland, Ohio
Cleveland Tungsten, Inc., 10200 Meech Ave., Cleveland 5, Ohio
Cleveland Wire Spring Co., 300 E Main St., DeSoto, Mo.
Cliff Mfg. Co., 30240 Lakeland Blvd., Wickliffe, Ohio
Climax Molybdenum Co., 500 5th Ave., New York 36, N. Y.
Clinton Metal Products Co., 1076 W Locust St., Wilmington, Ohio
Clopay Corp., Clopay Sq., Cincinnati 14, Ohio
Closures Inc., 46 State St., Waterbury, Conn.
Cly-Del Mfg. Co., Inc., Box 1367, Waterbury, Conn.
Coast Mfg. & Supply Co., P. O. Box 71, Livermore, Calif.
Coated Abrasive Products, Inc., 30208 Lakeland Blvd., Wickliffe, Ohio
Coated Coil Corp., 513 W 30th St., New York 1, N. Y.
Coating Products, 101 W Forest Ave., Englewood, N. J. (Ad p 267)
Cochran Foil Co., 1430 S 13th St., Louisville, Ky.
Cochrane Foundry Inc., Box 749, York, Pa.
Cohan Epner Co., Inc., 142 W 14th St., New York 11, N. Y.
Cold Metal Products Co., 2131 Wilson Ave., Youngstown, Ohio
Collis Co., Clinton, Iowa
Colonial Alloys Co., Ridge Ave. & Crawford St., Philadelphia 29, Pa.
Colonial Art Co., Inc., Crane Ave., Westfield, Mass.
Colonial Plastics Mfg. Co., 2685 E 79th St., Cleveland 4, Ohio
Colorado Fuel & Iron Corp., Continental Oil Bldg., Denver 2, Colo.
  Wickwire Spencer Steel Div., 575 Madison Ave., New York 22, N. Y.
Colt's Plastics Co., Inc., P. O. Box 119, Hartford, Conn.
Columbia Metal Stamping Co., 11900 Harvard Ave., Cleveland 5, Ohio
Columbia-National Corp., 70 Memorial Drive, Cambridge, Mass.
Columbia Tool Steel Co., Lincoln Hwy. & State St., Chicago Heights, Ill.
Columbian Bronze Corp., 216 Main St., Freeport, N. Y.
Columbiana Pump Co., Columbiana, Ohio
Columbus Bolt & Forging Co., 291 Marconi Blvd., Columbus 15, Ohio
Columbus Dental Mfg. Co., 634 Wager St., Columbus 6, Ohio
Columbus Jack Corp., 2200 S 3rd St., Columbus 7, Ohio
Columbus Production Mfg. Co., 935 W Goodale Blvd., Columbus 8, Ohio
Combined Industries Co., P. O. Drawer 431, Catskill, N. Y.
Combustion Engineering, Inc., Raymond Div., 1318 N Branch St., Chicago 22, Ill.
Comerford Mfg. Co., Inc., 81 Farmington Ave., Bristol, Conn.
Comet Metal Products Co. Inc., 9104 132nd St., Richmond Hill 18, N. Y.
Commercial Chemical Co., 1022 Summer, Cincinnati, Ohio
Commercial Plastics Co., Associated Plastic Div., 400 E Hines St., Midland, Mich.
Commercial Plastics & Supply Corp., 630 Broadway, New York 12, N. Y. (Ad p 182)
Commercial Shearing & Stamping Co., 1775 Logan Ave., Youngstown, Ohio
Compacted Metals Corp., 99 Greenwood Ave., Waukegan, Ill.
Composite Forgings, Inc., 2300 W Jefferson Ave., Detroit 16, Mich.
Compton Foundry, Compton, Calif.
Condamatic Co., Inc., 2700 E 9 Mile Rd., Hazel Park, Mich.
Conn Perry Mfg. Co., 4341 Horatio Ave., Detroit 10, Mich.
Conneaut Die Casting Co., 618 Sandusky St., Conneaut, Ohio
Conneaut Rubber & Plastics Co., Commerce St., Conneaut, Ohio
Connecticut Hard Rubber Co., 407 East St., New Haven 9, Conn. (Ad p 211)
Connecticut Malleable Castings Co., New Haven 6, Conn.
Connecticut Mfg. Co., 115 Benedict St., Waterbury 20, Conn.
Connell Asbestos Mfg. Co., 117 Martense St., Brooklyn 26, N. Y.
Conner Mfg. Co., 828 S 17th St., Louisville, Ky.
Conner Steel Products, 24690 Telegraph Rd., Detroit 19, Mich.
Consolidated Electrodynamics Corp., 1767 Mt. Reod Blvd., Rochester, N. Y.
Consolidated Foundries & Mfg. Corp., 135 S LaSalle, Chicago, Ill.
  Crucible Steel Casting Co., 2850 S 20th St., Milwaukee, Wis.
  Michigan Steel Casting Co., 1999 Guoin St., Detroit 7, Mich.
Consolidated Molded Products Corp., 1940 Thomas St., Scranton, Pa.
Consoweld Corp., 700 Hooker St., Wisconsin Rapids, Wis.
Continental Boiler & Sheet Iron Works, 5603 W Park Ave., St. Louis, Mo.
Continental Can Co., Inc., 100 E 42nd St., New York 17, N. Y.
  Conolite Div., 205 W 14th St., Wilmington, Del.
Continental Copper & Steel Industries Inc., 345 Madison Ave., New York 17, N. Y.
  Alloy Fabricators Div., 500 Market St., Perth Amboy, N. J.
  Niagara Falls Smelting & Refining Div., 2200-2214 Elmwood Ave., Buffalo 23, N. Y.
Continental Felt Co., 22 W 15th St., New York 11, N. Y. (Ad p 242)
Continental Foundry & Machine Co., 144th & Railroad Ave., East Chicago, Ind.
Continental Gin Co., Birmingham, Ala.
Continental Products Co., 1150 E 222nd St., Euclid 23, Ohio
Continental Rubber Works, 1985 Liberty St., Erie 6, Pa.
Continental Screw Co., 459 Mt. Pleasant St., New Bedford, Mass.
Continental Steel Works Corp., 1109 S Main St., Kokomo, Ind.
Continental Wire & Iron Works, Continental Nu-Steel Metal Products Div., 1249 S Ashland Ave., Chicago 8, Ill.
Contour Extrusion Co., 517 Fayette Ave., Mamaroneck, N. Y.
Conversion Chemical Corp., 98 E Main St., Rockville, Conn.
Cooley, W. J. & Co., P. O. Box 1471, 107 Hernando, Memphis, Tenn.
Cooper Alloy Corp., Bloy St. & Ramsey Ave., Hillside 5, N. J.
Cooper-Bessemer Corp., Mt. Vernon, Ohio
Cooper, Peter Co., Palmer St., Gowanda, N. Y.
Cooper's Creek Chemical Corp., River Rd., West Conshohocken, Pa.
Coors Porcelain Co., 600 9th St., Golden, Colo.
Copolymer Rubber & Chemical Corp., P. O. Box 2591, Baton Rouge 1, La.
Copperweld Steel Co., Warren, Ohio
  Ohio Seamless Tube Div., Shelby, Ohio (Ad p 325)
  Steel Div., Warren, Ohio
Cordo Chemical Corp., 34 Smith St., Norwalk, Conn.
Cordo Molding Products, Inc., 230 Park Ave., New York 1, N. Y.
Corite Products, Inc., 6553 W George St., Chicago 34, Ill.
Cornell & Underhill, Inc., 1310 Jefferson St., Hoboken, N. J.
Corning Glass Works, Corning, N. Y. (Ad p 241)
Couch-Uthe Co., 140 S Olive St., P. O. Box 339, Elyria, Ohio
Cox Plastics Corp., 162 Colgate Ave., Buffalo 20, N. Y.
Coyne & Paddock Inc., 40-09 21st St., Long Island City 1, N. Y.
Craft Mfg. Co., 3949 W Schubert Ave., Chicago 47, Ill.
Craftint Mfg. Co., 1615 Collamer Ave., Cleveland 10, Ohio
Crane Co., 836 S Michigan Ave., Chicago 5, Ill.
Crane Packing Co., 64 Oakton St., Morton Grove, Ill.
Crawford & Dougherty Foundry Co., 4604 SE 17th Ave., Portland, Ore.
Crescent Co., Inc., Carol Cable Div., 90 Middle St., Pawtucket, R. I.
Crescent Plastics, Inc., 955 Diamond Ave., Evansville 7, Ind.
Crest Chemical Industries Corp., 72 Delavan St., Brooklyn 31, N. Y.
Crobalt, Inc., 2800 S State St., Ann Arbor, Mich.
Cross Engineering Co., Carbondale, Pa.
Crown Metal Co., 117-127 E Washington St., Milwaukee 4, Wis.
Crown Non-Ferrous Foundry Inc., Concord Ave., Chester, Pa.
Crucible Steel Casting Co., Union Ave. & Penn R.R., Landsdowne, Pa.
Crucible Steel Co. of America, H. W. Oliver Bldg., Mellon Sq., Pittsburgh, Pa. (Ad p 136)
  Vacuum Metals Corp. Div., Syracuse 1, N. Y.
Crystal Plastics, Inc., 232 Taaffe Pl., Brooklyn 5, N. Y.
CrystalX Corp., W Lenni Rd., Lenni Mills, Pa.
Cuno Engineering Corp., S Vine St., Meriden, Conn.
Curtis Co., Inc., American Plywood Div., New London, Wis.
Curtis Screw Co., Inc., 19 Gull St., Buffalo 13, N. Y.
Curtiss-Wright Corp., 760 Northland Ave., Buffalo 15, N. Y. (Ad p 353)

Cuyahoga Stamping Co., 10201 Harvard Ave., Cleveland 5, Ohio
Cyril Bath Co., 32342 Aurora Rd., Solon, Ohio

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Dacar Chemical Products Co., 1007 McCartney St., Pittsburgh, Pa.
Dalton Foundries, Inc., Park & Lincoln Sts., Warsaw, Ind.
Damascus Tube Co., P. O. Box 71, Greenville, Pa.
Dana Corp., Parish Pressed Steel Div., Robinson & Weiser Sts., Reading, Pa.
Dapol Plastics, Inc., 90 Grove St., Worcester 5, Mass.
Darby Corp., 1st & Walker Sts., Kansas City 15, Kansas
Dare Products, Inc., 860 Betterly Rd., Battle Creek, Mich.
Darling, L. A. Co., Midwest Foundry Co. Div., Box 127, Coldwater, Mich.
Darlington Veneer Co., Inc., Darlington, S. C.
Daubert Chemical Co., 333 N Michigan Ave., Chicago, Ill.
Davidson Rubber Co., 50 Brighton St., Charlestown 29, Mass.
Davies, Harry Molding Co., 1428 N Wells St., Chicago 10, Ill.
Davis & Hemphill, Elkridge 27, Md.
Davis Products Corp., 603 39th St., Brooklyn, N. Y.
Dawlen Corp., 1911 Fargo Rd., Jackson, Mich.
Day Co., 810 3rd Ave. NE, Minneapolis 13, Minn.
Day, James B. & Co., 1872 Clybourn Ave., Chicago 14, Ill.
Dayton Bronze Bearing Co., 111 Front St., Dayton 2, Ohio
Dayton Foundry, 11803 Industrial Ave., Hollydale, Calif.
Dayton Malleable Iron Co., 1401 W 2nd St., Dayton, Ohio
  Meta-Mold Aluminum Co. Div., 525 E Hamilton, Cedarburg, Wis.
  Ohio Malleable Div., Box 88, Station A, Columbus, Ohio
  Pratt & Letchworth Div., 189 Tonawanda St., Buffalo 7, N. Y.
Dayton Steel Foundry Co., 1366 Miami Chapel Rd., Dayton 1, Ohio
Dearborn Stamping Co., 10501 Haggerty Ave., Dearborn, Mich.
Debevoise Co., 74-84 20th St., Brooklyn 32, N. Y.
Decatur Automatic Screw Machine Products Co., P. O. Box 26, Warrensburg, Ill.
Decatur Casting Co., 824 Dayton Ave., Decatur, Ind.
Decrow Engineering Corp., 62 Main St., Middleport, N. Y.
Deerfield Mfg. Co., 4th Ave., Mason, Ohio
Defiance Metal Products Co., 21 Seneca St., Defiance, Ohio
Defiance Stamping Co., Perry & Gorman Sts., Defiance, Ohio
Delaware Tool Steel Corp., 34th & Market Sts., Wilmington, Del.
Delo Screw Products Co., 38 S Franklin St., Delaware, Ohio
Delta Plywood Corp., Cotton Plant, Ark.
Dennis Chemical Co., 2701 Papin St., St. Louis 3, Mo.
Dependable Automatic Screw Co., 281 S Leonard St., P. O. Box 2179, Waterbury 8, Conn.
Derby Castings Co., 593 N Main St., Seymour, Conn.
DeSanno Foundry & Machine Co., 1919 Peralta St., Oakland 7, Calif.
Designers Metal Corp., 469 E 159th St., Harvey, Ill.
DeSoto Paint & Varnish Co., P. O. Box 186, Garland, Tex.
Detrex Chemical Industries, Inc., Box 501, RPK Annex 32, Detroit, Mich.
Detroit Chemical Works, 125 S Junction Ave., Detroit, Mich.
Detroit Float & Stamping Co., 625 Monroe St., Detroit, Mich.
Detroit Gasket & Mfg. Co., 12640 Burt Rd., Detroit 23, Mich.
Detroit Magnesium Castings Co., 6304 Epworth Blvd., Detroit 10, Mich.
Detroit Stamping Co., 350 Midland St., Detroit 3, Mich.
Detroit Steel Corp., Portsmouth Div., Detroit 9, Mich.
Dexter, C. H. & Sons Inc., Windsor Locks, Conn.
Diecast Corp., 522-524 Hupp Ave., Jackson, Mich.
Diemolding Corp., 125 Rasbach St., Canastota, N. Y.
Dietzel Lead Burning Co., Narrows Run Rd., Coraopolis, Pa.
Dimco-Gray Co., 207 E 6th St., Dayton 2, Ohio
Dip-Seal Plastics, Inc., 2311 23rd Ave., Rockford, Ill.
Dirilyte Co. of America, Inc., 1142 S Main St., Kokomo, Ind.
Disogrin Industries, Inc., New York International Airport, Jamaica 30, N. Y.
Diversey Corp., 1820 Roscoe St., Chicago 13, Ill.
Division Lead Co., 7742 W 61st Pl., Summit, Ill.
Dixie Aluminum Corp., 304 E 2nd Ave., Rome, Ga.
Dixie Bronze Co., 2229 27th Ave., N. Birmingham 1, Ala.
Dixie Lead Co., Sargent Rd., Dallas 16, Tex.
Dixie Plastics Mfg. Co., 3017 N Galves St., New Orleans, La.
Dixon Corp., Bristol, R. I.
Dixon, Joseph Crucible Co., Wayne & Monmouth Sts., Jersey City 3, N. J.
Dixon Sintaloy, Inc., 535 Hope St., Stamford, Conn.
Dodge Fibers Corp., John St., Hoosick Falls, N. Y.
Dodge Mfg. Corp., 500 S Union St., Mishawaka, Ind.
Dolin Metal Products, Inc., 315 Lexington Ave., Brooklyn 16, N. Y.
Dollin Corp., 650 S 21st St., Irvington 11, N. J. (Ad p 356)
Donegal Steel Foundry Co., 601 E Market St., Marietta, Pa.
Donovan, F. C. Inc., 192 South St., Boston, Mass.
Dormont Mfg. Co., 5607 Butler St., Pittsburgh 1, Pa.
Dostal Foundry & Machine Co., Pontiac, Mich.
Douglas & Sturgess, 475 Bryant St., San Francisco 7, Calif.
Dow Chemical Co., Townsend St., Midland, Mich.
Dow Corning Corp., P. O. Box 592, Midland, Mich.
Downington Iron Works, Inc., 161 Wallace St., Downington, Pa.
Dravo Corp., 102 5th Ave., Pittsburgh 22, Pa.
Drawn Metal Tube Co., 101 Elm St., Thomaston, Conn.
Dresser Industries, Inc., Republic National Bank Bldg., Dallas, Tex.
  Dresser Mfg. Div., 313 Fisher Ave., Bradford, Pa.
Drexel Screw Products Co., 6200 S Oakley Ave., Chicago 36, Ill.
Driver, Wilbur B. Co., 1875 McCarter Hwy., Newark, N. J. (Ad p 113)
Driver-Harris Co., 201 Middlesex St., Harrison, N. J.
du Pont de Nemours, E. I. & Co., Inc., Wilmington 3, Del. (Ad pp 186, 187)
Duane Specialties, Ltd., 210 Parkhurst St., Newark 5, N. J.
Du-Co Ceramics Co., Box 278, Saxonburgh, Pa.
Du-Lite Chemical Corp., Middletown, Conn.
Duluth Brass Works Co., 5002 Ramsey St., Duluth 7, Minn.
Dunnican Associates, 352 Plymouth Rd., Union, N. J.
Duplex Mfg. Corp., 104 Depot St., Sherman, N. Y.
Duplican Co., Inc., 1220 Turnpike Rd., Westboro, Mass.
Dura Flex Co., 2043 Colorado Ave., Santa Monica, Calif.
Dura Plastics of New York, Inc., 303 5th Ave., New York 16, N. Y.
Duralac Chemical Corp., 84 Lister Ave., Newark 5, N. J.
Dura-Lee Corp., 908 Broadway, Kansas City 5, Mo.
Duraloy Co., Scottdale, Pa.
Durethene Corp., 1859 S 55th Ave., Chicago 50, Ill.
Duriron Co., Inc., 450 N Findlay St., Dayton, Ohio
Duro Screw & Mfg. Co., 1064 Springfield Rd., P. O. Box 544, Union, N. J.
Du-Wel Metal Products, Inc., P. O. Box 307, Bangor, Mich.

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Eagle Convex Glass Specialty Co., 405-429 Tuna St., Clarksburg, W. Va.
Eagle-Picher Co., American Bldg., Cincinnati 1, Ohio
  Fabricon Products Div., 1721 Pleasant Ave., River Rouge 18, Mich. (Ad p 210)
Earl Paint Corp., 240 Genesee St., Utica 2, N. Y.
East Birmingham Bronze Co., 831 N 36th Way, Birmingham, Ala.
Eastern Brass & Copper Corp., 1122 E 180th St., New York 60, N. Y.
Eastern Machine Screw Corp., Truman & Barclay Sts., P. O. Box 1589, New Haven 6, Conn.
Eastern Malleable Iron Co., P. O. Box 349, Wilmington 99, Del.
Eastern Smelting & Refining Corp., 107 W Brookline St., Boston 18, Mass.
Eastern Stainless Steel Corp., Rolling Mill Rd., Baltimore, Md.
Eastern States Paint & Varnish Co., Water & Mifflin Sts., Philadelphia 48, Pa.
Eastern Tool & Mfg. Co., 1 Montgomery St., Belleville 9, N. J. (Ad p 342)
Eastman Chemical Products, Inc., Kingsport, Tenn.
Eastman Kodak Co., 343 State St., Rochester, N. Y.
Easton Metal Powder Co., Inc., 233 Broadway, New York 7, N. Y.
Easton Plastic Products Co., Inc., 900 Line St., Easton, Pa.
Eaton Mfg. Co., 9711 French Rd., Detroit, Mich.
Eberhard Faber Pencil Co., 37 Greenpoint Ave., Brooklyn, N. Y.
Eberhart Steel Products, Powdered Metals Div., 317 E Jefferson Blvd., Mishawaka, Ind.
Eby, Hugh H. Co., 4701 Germantown Ave., Philadelphia 20, Pa.
Eclipse Plastic Industries, Inc., Box 430, Sarasota, Fla.
Economy Machine Products Co., 5214 W

Addresses of Suppliers

Lawrence Ave., Chicago 30, Ill.
Edgar Plastic Kaolin Co., Edgar, Fla.
Edna Lite Optical Co., Inc., 200 N Water St., Peekskill, N. Y.
Egan & Housman Co., Inc., 43rd Rd. & 9th St., Long Island City 1, N. Y.
Egyptian Lacquer Mfg. Co., P. O. Box 444, Newark 1, N. J.
Ekstrand & Tholand, 420 Lexington Ave., New York 17, N. Y.
Elastomer Chemical Corp., 212 Wright St., Newark 7, N. J.
Elchingler, Charles F., 916 Magazine St., New Orleans 12, La.
Elco Tool & Screw Corp., 1800 Broadway, Rockford, Ill.
Electric Materials Co., Clay & Washington Sts., North East, Pa.
Electric Steel Castings Co., 1045 Main St. Speedway, Indianapolis 24, Ind.
Electric Steel Foundry Co., 2141 NW 25th Ave., Portland 10, Ore.
Electric Storage Battery Co., Stokes Molded Products Div., Taylor St. & Webster, Trenton 4, N. J.
Electrical Refractories Co., E Clark St., East Palestine, Ohio
Electron Corp., Box 208, Littleton, Colo.
Electronic Parts Mfg. Co., Inc., 508 25th St., Union City, N. J.
Elgin National Watch Co., 107 National St., Elgin, Ill.
Eljay Corp., 2900 Herbert St., Baltimore 16, Md.
Elkhart Iron Works, 1221 Broad St., St. Joseph, Mich.
Elsby, J. S. Inc., 3223 W Burnham St., Milwaukee 15, Wis.
Emco Porcelain Enamel Co., Inc., Abendroth Ave. & Highland St., Port Chester, N. Y.
Emerson-Sack-Warner Corp., 85 Washington St., Somerville, Mass.
Emjay Maintenance Engineers, 327 Union Ave., Rutherford, N. J.
Empire Aluminum Co., 4021 Mahoning Ave., Youngstown, Ohio
Empire Metal Co., 820 E Water St., Syracuse 3, N.Y.
Empire Pattern & Foundry Co., P. O. Box 1647, Tulsa 1, Okla.
Empire Spring Co., 210 S Abbe St., Elyria, Ohio
Empire Steel Castings, Inc., Brush Valley Rd., Temple, Pa.
Enamel Products Co., 341 Eddy Rd., Cleveland 8, Ohio
Endicott Forging & Mfg. Co., Inc., 1901 North St., Endicott, N. Y.
Engineered Nylon Products, Inc., 1318 S Olive St., South Bend, Ind.
Engineered Plastics & American Sinterings Inc., Silk St., Watertown, Conn.
Engineered Precision, Castings Co., Hwy. 79, P. O. Box 68, Matawan, N. J.
Engineering Products & Specialties Inc., Dunnel Lane, Pawtucket, R. I.
Englander Co., Inc., Plastics Div., 227 N Warwick Ave., Baltimore 23, Md.
Enjay Co., Inc., 15 W 51st St., New York 18, N. Y.
Enterprise Galvanizing Co., 2507 E Comberland St., Philadelphia 25, Pa.
Enterprise Wheel & Car Corp., P. O. Box 151, Bristol, Va.
Enthone, Inc., 442 Elm St., New Haven, Conn.
Erie Bronze Co., 19th & Chestnut Sts., Erie, Pa.
Erie Ceramic Arts Co., 3120 W 22nd St., Erie, Pa.
Erie Enameling Co., 1400 W 20th St., Erie, Pa.
Erie Scientific Corp., Industrial Center, Buffalo 10, N. Y.
Erskine Precision Wire Corp., 210 S Broad St., Emporium, Pa.
Ervite Corp., P. O. Box 1927, Erie, Pa.
Essential Bar Products Co., 2526 Brooklyn Rd., Jackson, Mich.
Essex Wire Corp., 1601 Wall St., Ft. Wayne, Ind.
Est Co., Inc., Grafton, Wis.
Etched Products Corp., 39-01 Queens Blvd., Long Island City 4, N. Y.
Eureka Electrical Products Co., Clay St., North East, Pa,
Evans, George Corp., 121 37th St., Moline, Ill.
Evans Metal Co., 740 Lambert Dr. NE, Atlanta, Ga.
Evans Products Co., P. O. Box 651, Corvallis, Ore.
Evans-Winter-Hebb Inc., 818 W Hancock Ave., Detroit, Mich.
Everhead Tap & Die Corp., 215 E 144th St., New York 51, N. Y.
Everlite Corp., 2040 15th Ave. W, Seattle 99, Wash.
Exalco Mfg. Co., 46 Sheldon Rd., Berea, Ohio (Ad p 332)
Exeter Mfg. Co., Exeter, N. H.
Extruders, Inc., 3232 W El Segundo Blvd., Hawthorne, Calif.
Eyelet Specialty Co., 46 State St., Waterbury, Conn.

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Fahralloy Co., 149th & Loomis Sts., Harvey, Ill. (Ad p 315)
Fairchild Screw Products, Inc., White St., P. O. Box 497, Winsted, Conn.
Fairfield Aluminum Castings Co., 603 N 8th St., Fairfield, Iowa
Fairmont Aluminum Co., Fairmont, W. Va.
Falge Engineering Corp., 4733 Elm St., Bethesda 14, Md.
Falls Machine Co., 1625 Massillon Rd., Akron 12, Ohio
Fallstrom Co., Fallstrom Court, Passaic, N. J.
Fanner Mfg. Co., Murray Products, Inc., 12388 Crossham Ave., Cleveland, Ohio
Fansteel Metallurgical Corp., 2200 Sheridan Rd., N. Chicago, Ill. (Ad pp 134, 135)
Farley & Loetscher Mfg. Co., Plastics Div., 7th & White, Dubuque, Iowa
Farnam Mfg. Co., 2000 Sweeten Creek Rd., Asheville, N. C.
Farrel-Birmingham Co., Inc., 25 Main St., Ansonia, Conn.
Farrelloy Co., 1234-45 N 26th St., Philadelphia 21, Pa.
Farwell Metal Fabricating, 77 W Fairfield Ave., St. Paul 7, Minn.
Federal Adhesives Corp., 210 Wythe Ave., Brooklyn 11, N. Y.
Federal Die Casting Co., 2226 N Elston, Chicago, Ill.
Federal Screw Works, Congdon St., Chelsea, Mich.
Federal Steel Products Corp., 415 N St. Charles St., Houston 3, Tex.
Federal Tool Corp., 3600 W Pratt Blvd., Chicago 45, Ill.
Federal Tool & Mfg. Co., 3600 Alabama Ave., Minneapolis 16, Minn.
Felters Co., 210 South St., Boston 11, Mass. (Ad pp 238, 239)
Felton, Sibley & Co., Inc., 136 N 4th St., Philadelphia 6, Pa.
Femco Mfg. Co., Inc., 22845 Hoover Rd., Detroit 5, Mich.
Ferro Corp., 4150 E 56th St., Cleveland 5, Ohio
Ferro Enameling Co., 1100 57th Ave., Oakland 21, Calif.
Ferro Powdered Metals, Box 312, Salem, Ind.
Ferro-co Corp., Schori Process Div., 8-11 43rd Rd., Long Island City 1, N. Y.
Fetcher, M. B. Co., 3558 Garfield St., Detroit 7, Mich.
Fiber Glass-Industries, Inc., Homestead Pl., Amsterdam, N. Y.
Fibercast Corp., 100 S Lincoln, Sand Springs, Okla.
Fiberfil, Inc., Fox Farm Rd., Warsaw, Ind.
Fiberite Corp., 510-524 W 4th St., Winona, Minn.
Fibron Products, Inc., 45 Mechanic St., Buffalo 2, N. Y.
Fidelity Chemical Products Corp., 470-474 Frelinghuysen Ave., Newark 12, N. J.
Fidelity Felt & Mfg. Co., 22 W 15th St., New York 11, N. Y.
Figley Die & Stamping Co., 401 Agnes St., Defiance, Ohio
Filpaco Industries, Inc., 2426 S Michigan Ave., Chicago 16, Ill.
Fine Organics, Inc., 209-211 E 19th St., New York, N. Y.
Firestone Plastics Co., Firestone Blvd., Pottstown, Pa.
Firestone Tire & Rubber Co., 1200 Firestone Pkwy., Akron 17, Ohio
Firth Sterling, Inc., 3113 Forbes St., Pittsburgh, Pa.
Fischer Casting Co., Inc., P. O. Box M, Dunellen, N. J.
Fischer & Porter Co., 105 Warminster Rd., Hatboro, Pa.
Fischer Special Mfg. Co., 450 Morgan St., Cincinnati 20, Ohio
Fish-Schurman Corp., 70 Portman Rd., New Rochelle, N. Y.
Fitzgibbons Boiler Co., Inc., 101 Park Ave., New York, N. Y.
FitzSimons Mfg. Co., 3775 E Outer Dr., Detroit 34, Mich.
Fletcher Enamel Co., Dunbar, W. Va.
Flexfirm Products, 2300 N Chico Ave., El Monte, Calif.
Flexonics Corp., 1315 S 3rd Ave., Maywood, Ill.
Flightex Fabrics, Inc., 93 Worth St., New York 13, N. Y.
Ostby & Barton Co., 148 W River St., Providence 4, R. I.
Flood City Brass & Electric Co., Messenger & Elder Sts., Johnstown, Pa.
Flood Co., Barlow Rd., Hudson, Ohio
Florence Pipe Foundry & Machine Co., Front St., Florence, N. J.
Florin Foundry & Mfg. Co., Florin, Pa.
Flynn & Emrich Co., 301 Holliday St., Baltimore 2, Md.
Flynn, Michael Mfg. Co., 700 E Godfrey Ave., Philadelphia 24, Pa.
Foamade Industries, 14851 W 11 Mile Rd., Oak Park 37, Mich.
Follansbee Steel Corp., Sheet Metal Specialty Div., P. O. Box 567, Follansbee, W. Va.
Food Machinery & Chemical Corp., Ohio-Apex Div., Nitro, W. Va.
Foote Mineral Co., 18 W Chelten Ave., Philadelphia 44, Pa.
Fordsell Machine Products Co., 4433 E 8th Mile Rd., Van Dyke, Mich.
Forest Fiber Products Corp., P.O. Box 68, Forest Grove, Ore.
Forg, Peter Mfg. Co., 50 Park St., Somerville 43, Mass.
Forman, Ford & Co., S 2nd St., Minneapolis 1, Minn.
Formed Tubes, Inc., Prairie & Albert Sts., Sturgis, Mich.

Bold face indicates supplier advertises in this issue

Formica Corp., 4614 Spring Grove Ave., Cincinnati 32, Ohio
Formold Plastics, Inc., Box 103, Blue Island, Ill.
Foss Mfg. Co., 225 2nd Ave., Twin Falls, Id.
Foster Aluminum Alloy Products Corp., Pearl St., Forestville, N. Y.
Foster Grant Co., Inc., 289 N Main St., Leominster, Mass.
Foster Wheeler Corp., 165 Broadway, New York, N. Y.
Foundry Rubber, Inc., 5200 River Rd., Washington 16, D. C.
Fox Co., 3400 Beekman St., Cincinnati 23, Ohio
Fox Edge Co., Inc., 1995 Middlesex St., Lowell, Mass.
Fox Products Co., 4720 N 18th St., Philadelphia 41, Pa.
Franklin Glue Co., 119 Chestnut St., Columbus 15, Ohio
Franklin Mineral Co., Box 28, Franklin, N. C.
Franklin Plastics, Inc., 315 Grant St., Franklin, Pa.
Frasse, Peter A. & Co., Inc., 17 Grand St., New York 13, N. Y.
Frederick Iron & Steel, Inc., 7th & East Sts., Frederick, Md.
Frenchtown Porcelain Co., 84 Muirhead Ave., Trenton, N. J.
Friedrich & Dimmock, Inc., Main Rd. & Lincoln Ave., Millville, N. J.
Frisby, J. R. Mfg. Co., 246 N Western Ave., Chicago 12, Ill.
Fromson Orban Co., Inc., 261 Madison Ave., New York 16, N. Y. (Ad p 127)
Frontier Bronze Corp., 4870 Packard Rd., Niagara Falls, N. Y.
Frost Paint & Oil Co., 1203 NE Tyler, Minneapolis, Minn.
Frost Rubber Co., 1407 N Dayton St., Chicago 22, Ill.
Fry Plastics Co., 7826 S Vermont Ave., Los Angeles 44, Calif.
Fryling Mfg. Co., 531 W 11th St., Erie, Pa.
Fuller, W. P. & Co., 301 Mission St., San Francisco, Calif.
Fullerton Mfg. Co., 343 E Santa Fe Ave., Fullerton, Calif.
Fulton Foundry & Machines Co., Inc., Cleveland, Ohio
Fulton Gold Refiners Corp., 71 Fulton St., New York 38, N. Y.
Funkhouser Co., 138 W Washington St., Hagerstown, Md.
Furane Plastics, Inc., 4516 Brazil St., Los Angeles 39, Calif.

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G & G Mfg. Co., 3223 W Fillmore St., Chicago 24, Ill.
G & Z Automatic Products Co., 2434 Brooklyn Rd., P. O. Box 347, Jackson, Mich.
Gale Mfg. Co., 115 N Albion St., Albion, Mich.
Gamble Bros., Inc., 4601 Louisville Ave., Louisville, Ky.
Gantner Screw Products Co., Inc., 20 S Walnut St., Springfield, Ohio
Garco Mfg. Co., Inc., 744 N Ada St., Chicago 22, Ill.
Garfield Mfg. Co., 10 Midland Ave., Garfield, N. J.
Garlock Packing Co., Main St., Palmyra, N. Y.
  U.S. Gasket Div., Camden 1, N. J.
Gartland-Haswell Foundry Co., 430 W Park St., Sidney, Ohio
Gary Steel Products Corp., P. O. Box 449, Lynchburg, Va.
Gates Engineering Co., 100 S West St., Wilmington 99, Del.
Gates Rubber Co., 999 S Broadway, Denver, Colo.
Gatke Corp., 228 N LaSalle St., Chicago 1, Ill.
Geauga Industries Co., Middlefield, Ohio
General Alloys Co., 367-405 W 1st St., South Boston 27, Mass. (Ad p 334)
General Aluminum Mfg. Co., 3027 E 55th St., Cleveland 27, Ohio
General American Transportation Corp. 135 S LaSalle St., Chicago 90, Ill.
  Kanigen Div., 135 S LaSalle St., Chicago 90, Ill.
  Plastics Div., 135 S LaSalle St., Chicago 90, Ill.
  Plate & Welding Div., 135 S LaSalle St., Chicago 90, Ill.
General Aniline & Film Corp., Antara Chemicals Div., 435 Hudson St., New York 14, N. Y.
General Cable Corp., 420 Lexington Ave., New York 17, N. Y.
General Ceramics Corp., Crows Mill Rd., Keasbey, N. J.
General Electric Co., 1 River Rd., S Schenectady 5, N. Y.
  Apparatus Sales Div., 1 River Rd., Schenectady 5, N. Y.
  Chemical Materials Dept., Pittsfield, Mass.
  Foundry Dept., 1 River Rd., Schenectady 5, N. Y.
  Insulating Materials Dept., 69 River Rd., Schenectady 5, N. Y.
  Laminated & Insulating Products Dept., Coshocton, Ohio
  Lamp Wire & Phosphors Dept., 1331 Chardon Rd., Cleveland 17, Ohio
  Silicone Products Dept., Waterford, N. Y. (Ad p 197)
General Engineering Works, 4701 W Division St., Chicago 51, Ill.
General Extrusions, Inc., 4040 Lake Park Rd., Youngstown, Ohio
General Findings & Supply Co., Industrial Div., Leach & Garner Bldg., Attleboro, Mass.
General Foundry & Mfg. Co., Flint, Mich.
General Industries Co., Plastics Div., Clive & Taylor Sts., Elyria, Ohio
General Iron Works Co., P. O. Box 2490, Denver 1, Colo.
General Malleable Corp., 706 E Main St., Waukesha, Wis.
General Metals Powder Co., 130 Elinor Ave., Akron 5, Ohio
General Mills, Inc., Chemical Div., S Kensington Rd., Kankakee, Ill.
General Motors Corp., General Motors Bldg., Detroit, Mich.
  Central Foundry Div., 37 Florence St., Saginaw, Mich.
  Moraine Products Div., 1420 Wisconsin Blvd., Dayton 1, Ohio
General Paint Corp., P.O. Box 3474, Rincon Annex, San Francisco, Calif.
General Plastics Corp., 1400 N Washington St., Marion, Ind.
General Plastics Corp., 165 3rd Ave., Paterson 4, N. J. (Ad p 270)
General Plastics Mfg. Co., 3481 S 35th St., Tacoma 9, Wash.
General Powdered Metal Products, Inc., Holly Corp., 523 West Ave., Norwalk, Conn.
General Screw Products Corp., 1190 Brooks Ave., Rochester 19, N. Y.
General Sintering Corp., 1830 N 32nd Ave., Melrose Park, Ill.
General Smelting Co., 2901 E Westmoreland St., Philadelphia 34, Pa.
General Tire & Rubber Co., Factory Ave., Marion, Ind.
Genesee Laboratory, Inc., 16 Garden St., Auburn, N. Y.
Geometric Stamping Co., 1111 E 200th St., Cleveland 17, Ohio
George, P. D. Co., 5100 N 2nd, St. Louis, Mo.
Georgia Iron Works, Augusta, Ga.
Georgia Kaolin Co., 433 N Broad St., Elizabeth, N. J.
Georgia-Pacific Corp., 600 N Capitol Way, Olympia, Wash.
Gering Products, Inc., N 7th St. & Monroe, Ave., Kenilworth, N. J.
Gertenslager Co., E Bowman St., Wooster, Ohio
Geuder Paeschke & Frey Co., 1538 W St. Paul Ave., Milwaukee 1, Wis.
Giant Grip Mfg. Co., 29 Osceola St., Oshkosh, Wis.
Gibb, Walton Leather Co., 54th & Grays Ferry Ave., Philadelphia 43, Pa.
Gibson Electric Co., 8356 Frankstown Ave., Pittsburgh 21, Pa.
Gibson & Kirk Co., Warner & Bayard St., Baltimore 30, Md.
Gilbert Brass Foundry Co., 5036 Farlin Ave., St. Louis 15, Mo.
Gillespie Varnish Co., 131 Dey St., Jersey City 6, N. J.
Gillet & Eaton, Inc., 8th & Doughty, Lake City, Minn.
Glamorgan Pipe & Foundry Co., P. O. Box 740, Lynchburg, Va.
Glasby, J. P. Mfg. Co., Inc., 1 Montgomery St., Bellevue 9, N. J.
Glaskyd, Inc., 125 W 3rd St., Perrysburg, Ohio
Glass Laboratories, Inc., 865 65th St., Brooklyn 20, N. Y. (Ad p 359)
Glastic Corp., 4321 Glenridge Rd., Cleveland 21, Ohio
Glenn, Joseph & Sons, Inc., Clifton Heights, Pa.
Glidden Co., Chemicals-Pigments-Metals Div., 1717 Summer St., Hammond, Ind. (Ad p 321)
Globe Imperial Corp., Plastic-Seal Div., 2038 Kishwaukee, Rockford, Ill.
Globe Industries, Inc., Supermet Div., 1470 Cincinnati St., Dayton 8, Ohio (Ad p 334)
Globe Paint Works, Inc., Box 36, Williamsport, Pa.
Globe Union, Inc., Centralab Div., 900 E Keefe Ave., Milwaukee 1, Wis.
Glo-Brite Products, Inc., 6415 N California Ave., Chicago 45, Ill.
Glover Machine Works, Butler St., Marietta, Ga.
Gluntz Brass & Aluminum Foundry Co., 10815 Harvard Ave., Cleveland 5, Ohio
Gockel Leather Shop, 31875 Aurora Rd., Solon, Ohio
Gold Leaf & Metallic Powders, Inc., 145 Nassau St., New York 38, N. Y.
Goldsmith Bros., S. & R. Co., 111 N Wabash Ave., Chicago 2, Ill.
Gomar Mfg. Co., Inc., 1501 W Blancke St., Linden, N. J.
Goodrich, B. F. Chemical Co., 3135 Euclid Ave., Cleveland 15, Ohio
  Hood Rubber Co., 99 Nichols Ave., Watertown, Mass.
  Industrial Products and Plastic Products Divs., Marietta, Ohio
Goodrich-Gulf Chemicals, Inc., 3121 Euclid Ave., Cleveland 15, Ohio
Goodyear Tire & Rubber Co., 1144 East Market St., Akron 16, Ohio
Gordon Chemicals, Inc., 500 "A" St., Wilmington 99, Del.
Goshen Rubber Co., Inc., 1525 S 19th St., Goshen, Ind. (Ad p 211)
Gotham Plastics Corp., 220 E 134th St., New York 51, N. Y.
Gowanda Furnaces, Inc., 7 Palmer St., Gowanda, N. Y.

Addresses of Suppliers

Grace, W. R. & Co., 7 Hanover Square, New York, N. Y.
Dewey & Almy Chemical Div., 62 Wittemore Ave., Cambridge 40, Mass.
Polymer Chemicals Div., 225 Allwood Rd., Clifton, N. J. (Ad p 217)
Grafton Foundry Co., 1003 Bridge St., Grafton, Wis.
Graham, James Co., 293 Wooster St., New Haven, Conn.
Grammes, L. F. & Sons, Inc., 380 Union St., Allentown, Pa.
Grand Haven Stamped Products, Griffen & Madison Sts., Grand Haven, Mich.
Grand Rapids Brass Co., 420 50th St. SW, Grand Rapids 8, Mich.
Grand Rapids Varnish Corp., 1350 Stelle St. SW, Grand Rapids 2, Mich.
Grand Sheet Metal Products Co., Consumer Products Div., 2055 Ruby St., Melrose Park, Ill.
Granite City Steel Co., 20th & Madison Aves., Granite City, Ill.
Graphite Metallizing Corp., 1058 Nepperhan Ave., Yonkers 3, N. Y. (Ad p 360)
Graphite Specialties Corp., 64th St. & Pine Ave., Niagara Falls, N. Y. (Ad p 242)
Grass, M. J. Screw Machine Products Co., 19 Northampton St., Buffalo 9, N. Y.
Graver Tank & Mfg. Co., Inc., 6300 Tod Ave., East Chicago, Ind.
Gray-Syracuse, Inc., 116 W Seneca St., Manlius, N. Y. (Ad p 346)
Great American Industries, Inc., Rubatex Div., Bedford, Va.
Greenback Industries, Inc., 2527 W Maple Rd., Birmingham, Mich.
Greene, G. G. Corp., Warren, Pa.
Greene Mfg. Co., 1028 Douglas Ave., Racine, Wis.
Greenfield, Samuel Co., Inc., 31 Stone St., Buffalo 12, N. Y.
Greenlee Foundries, Inc., 662 W Roosevelt Rd., Chicago 7, Ill.
Greenlee Foundry Co., Div., 4600 W 14th St., Chicago 50, Ill.
Gregg Metal Products Co., 1333 N 9th St., Milwaukee 5, Wis.
Grems Mfg. Co., 5635 S 6th St., Klamath Falls, Ore.
Grey, C. M. Industries, 358 Central Ave., East Orange, N. J.
Gries Reproducer Corp., 125 Beechwood Ave., New Rochelle, N. Y.
Grimes Mfg. Co., Plastic Research Products Div., 200 Beech St., Urbana, Ohio
Grimm Foundry Co., Inc., Chimney Rock Rd., Bound Brook, N. J.
Grip Nut Co., South Whitley, Ind.
Gross, Willard N. Inc., 224 Highland Ave., Westmont, Collingswood, N. J.
Guarantee Specialty Mfg. Co., 9651 Carr Ave., Cleveland 8, Ohio
Guilfoy Cornice Works, 1234 Howard St., San Francisco 3, Calif.
Gumm, Frederick Chemical Co., Inc., 538 Forest St., Kearny, N. J.
Gunite Foundries Corp., 302 Peoples Ave., Rockford, Ill.
Gusmer, A. Inc., Upper Barron Ave., Woodbridge, N. J.
Gustin-Bacon Mfg. Co., 210 W 10th St., Kansas City 5, Mo.

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H & H Foundry Machine Co., P. O. Box 238, Jeannette, Pa.
H & H Screw Products, Inc., 570 Elk St., Buffalo 10, N. Y.
H. & H. Screw Products Mfg. Co., 1883 Mineral Spring Ave., North Providence 11, R. I.
H & H Tube & Mfg. Co., 247-275 N Forman Ave., Detroit 17, Mich.
H. & K. Machine Service Co., Inc., 6229 Bartmer Ave., St. Louis, Mo.
H-P Products, Inc., 510 W Broad St., Louisville, Ohio
H P L Mfg. Co., 15210 Miles Ave., Cleveland 28, Ohio
H & R Industries, 344 E Walnut St., Nazareth, Pa.
Haber Corp., 864 W North Ave., Chicago 22, Ill.
Hack, J. H. Mfg. Co., 7049 Lyndon Ave., Detroit 21, Mich.
Haffner Bros. Co., Hopple St. & Central Pkwy., Cincinnati 25, Ohio
Hagstoz, T. B. & Son, 709 Sansom St., Philadelphia 6, Pa.
Haigh Mfg. Co., 225 E Grand River, Brighton, Mich.
Hall Mfg. Corp., 175 Linden St., Hackensack, N. J.
Hamilton Die Cast, Inc., 240 N B St., Hamilton, Ohio
Hamilton Foundry & Machine Co., 1556 Lincoln Ave., Hamilton, Ohio
Hammond Plastics, Inc., 88 Webster St., Worcester, Mass.
Hampden Brass & Aluminum Co., 262 Liberty St., Springfield, Mass.
Handy & Harman, 82 Fulton St., New York 38, N. Y.
Hanford Foundry Co., 119 S Arrowhead Ave., San Bernardino, Calif.
Hanline Bros., 1400 Warner St., Baltimore 30, Md.
Hanovia Chemical & Mfg. Co., 1 Central Ave., East Newark, N. J.
Harback Mfg. Co., Orange, N. J.
Harcast Co., 620 E Glenolden Ave., Glenolden, Pa.
Hardinge Mfg. Co., York, Pa.
Hardman, H. V. & Co., 571 Cortlandt St., Belleville, N. J.
Hardy, Charles Inc., 420 Lexington Ave., New York 17, N. Y.
Hardy Mfg. Corp., W Pearl St., Union City, Ind.
Harford Machine Screw Co., 92 Deerfield Rd., Wilson, Conn.
Harnischfeger Corp., 400 W National Ave., Milwaukee, Wis.
Harper, H. M. Co., 8200 Lehigh Ave., Morton Grove, Ill.
Harries, Benjamin & Co., 11th & State Sts., Chicago Heights, Ill.
Harrington & King Perforating Co., Inc., 5655 Fillmore St., Chicago 44, Ill.
Harrison Paint & Varnish Co., 1329 Harrison Ave. SW, Canton 1, Ohio
Harsco Corp., Precision Castings Div., P. O. Box 1077, Syracuse, N. Y.
Harshaw Chemical Co., 1945 E 97th St., Cleveland 6, Ohio
Harte & Co., Inc., 16 E 24th St., New York, N. Y.
Hartwell, H. N. & Son Inc., 947 Park Square Blvd., Boston 16, Mass. (Ad p 204)
Harvey Machine Co., Inc., Harvey Aluminum Div., 19200 S Western Ave., Torrance, Calif.
Harvill Corp., 6241 W Century Blvd., Los Angeles 45, Calif.
Harvin & Co., Box 83, Federal St., Kenilworth, N. J.
Harwood Screw Products, Inc., 1620 E Pleasant St., Springfield, Ohio
Haskelite Mfg. Corp., 701 Ann St. NW, Grand Rapids, Mich.
Hassel, John Inc., Cantigue Rd., Westbury, L. I., N. Y. (Ad p 314)
Hastings & Co., Inc., 2316 Market St., Philadelphia, Pa.
Haveg Corp., 900 Greenbank Rd., Wilmington 8, Del.
Hawkeye Rubber Mfg. Co., 915 Shaver Rd. NE, Cedar Rapids, Iowa
Hawkridge Bros. Co., 303 Congress St., Boston 10, Mass.
Hay, James E. Leather Co., 244 Smith St., Lowell, Mass.
Hayden Wire Works, 31 Sylvan St., West Springfield, Mass.
Hayman, Michael & Co., Inc., 856 E Ferry St., Buffalo 11, N. Y.
Hays Mfg. Co., 803 W 12th St., Erie, Pa.
Hazledine, E. T. Co., 231 S 1st St., Terre Haute, Ind.
Headly Mfg. Co., 4376 W Ogden Ave., Chicago 23, Ill.
Heat Bath Corp., P. O. Box 78, Springfield 1, Mass.
Heavy Minerals Co., 4000 N Hawthorne St., Chattanooga, Tenn.
Heil Process Equipment Corp., 12901 Elmwood Ave., Cleveland 11, Ohio
Heintz Mfg. Co., Front St. & Olney Ave., Philadelphia 20, Pa.
Held, O. P. Inc., 1947 Hammersley Ave., Bronx 69, N. Y.
Heller, A. B. Products, Inc., 14571 Lesure Ave., Detroit 27, Mich.
Heller Tool Co., Heller Dr., Newcomerstown, Ohio
Helmick Foundry-Machine Co., P. O. Box 71, Fairmont, W. Va.
Hendrick Mfg. Co., Dundaff St., Carbondale, Pa.
Henefelt Precision Products, 1630 Herald Ave., Cincinnati 12, Ohio
Henning Bros. & Smith, Inc., 91-113 Scott Ave., Brooklyn 37, N. Y.
Henrite Products Corp., Ironton, Ohio
Heppenstall Co., 4620 Hatfield St., Pittsburgh 1, Pa.
Hercules Fastener Co., 2722 N Clybourn St., Chicago 14, Ill.
Hercules Powder Co., Wilmington, Del.
Heresite & Chemical Co., Manitowoc, Wis.
Herker Screw Products, Inc., 4924 N 125th St., Butler, Wis.
Herman Machine & Tool Co., Tallmadge, Ohio
Hershey Metal Products, Inc., Derby, Conn.
Hess, Goldsmith & Co., Inc., 1400 Broadway, New York 18, N. Y.
Hettleman, K. & Sons, Inc., 9th & Patapsco Aves., Baltimore 25, Md.
Hewitt, John Foundry Co., 15-29 Sherman Ave., East Newark, N. J.
Hewitt-Robins, Inc., 666 Glenbrook Rd., Stamford, Conn.
Hexcel Products, Inc., 951 61st St., Oakland 8, Calif.
Heypian Mfg. Co., Meinigin Ave., Kenilworth 19, N. J.
Hibben & Co., 9376 S Ewing Ave., Chicago, Ill.
Hica, Inc., 1431 W 59th St., Shreveport, La.
Hicks Corp., Hyde Park Ave., Boston, Mass.
Higbie Mfg. Co., Avon Tube Div., Harper Rd., Rochester, Mich.
Hi-Grade Alloy Corp., 1236 S Tallman St., Chicago, Ill.
Hilfinger Corp., 1800 Westwood Ave., Toledo 7, Ohio
Hills-McCanna Co., 3025 N Western Ave., Chicago 18, Ill.
Hilo Varnish Corp., Industrial Finishes Div., Carpenter-Morton Co., 376 3rd St., Everett 49, Mass.
Himmel Bros. Co., 1409 Dixwell Ave., Hamden, Conn.
Hitchiner Mfg. Co., Inc., P. O. Box 232, Milford 6, N. H.
Hobart Bros. Co., 1221 Hobart Rd., Troy, Ohio
Hobbs, Clinton E. Co., 203 Chelsea St., Everett 49, Mass.

Hodges, William E. & Co., Inc., 1627 N American St., Philadelphia 2, Pa.
Hodgeson Foundry Co., 2012 W 13th St., Chicago 8, Ill.
Hoeganaes Sponge Corp., Taylor Lane & River Rd., Riverton, N. J.
Hoffman Bronze & Aluminum Castings Co., 1000 Addison Rd., Cleveland 3, Ohio
Hofford Varnish Co., Inc., Broad & 14th Sts., Carlstadt, N. J.
Hohwieler Rubber Co., Inc., 32 Bridge St., Morrisville, Pa.
Hokin Aluminum Co., 142nd St. & Cottage Grove, Dolton, Ill.
Hollingsworth & Vose Co., Washington St., East Walpole, Mass. (Ad p 240)
Holt Products Co., Walnut St., Holt, Mich.
Home Rubber Co., 30 Woolverton Ave., Trenton, N. J.
Homestead Valve Mfg. Co., P. O. Box 348, Coraopolis, Pa.
Hommel, O. Co., 209 4th Ave., Pittsburgh, Pa.
Hoofer Mfg. Co., 544 W Lake St., Chicago 6, Ill.
Hooker Electrochemical Co., 51 47th St., Niagara Falls, N. Y.
Durez Plastics Div., 1967 Walck Rd., North Tonawanda, New York (Ad pp 214, 215)
Hoover Co., Die Casting Div., 101 E Maple St., North Canton, Ohio
Hoskins Mfg. Co., 4445 Lawton Ave., Detroit 8, Mich.
Houghton, E. F. & Co., 303 W Leigh Ave., Philadelphia 33, Pa.
Houghton Laboratories, Inc., 338 Bush St., Olean, N. Y. (Ad p 213)
Houston Blow Pipe & Sheet Metal Works, P. O. Box 1692, Houston 1, Tex.
Houston Porcelain Enameling Co., 1130 Sidco Rd., Houston, Tex.
Houze Glass Corp., Point Marion, Pa.
Howard Foundry Co., 1700 N Kostner Ave., Chicago 39, Ill.
Hoyt, Charles D. Co., Inc., 1118 Forest Ave., Mishawaka, Ind.
Huck Mfg. Co., 2480 Bellevue Ave., Detroit 7, Mich.
Hudson Screw Machine Products Co., 4500 W Augusta Blvd., Chicago 51, Ill.
Hudson Smelting & Refining Co., 567 Wilson Ave., Newark 5, N. J.
Hudson Wire Co., Upper Dock, Ossining, N. Y.
Hughes Glue Co., 3500 St. Aubin St., Detroit 7, Mich.
Hughes Tool Co., 5425 Polk Ave., P. O. Box 2539, Houston 1, Tex.
Hull, R. O. & Co., Inc., 1300 Parsons Court, Rocky River 16, Ohio
Hungerford Plastics Corp., Hanover Ave., Morristown, N. J.
Hunt Screw & Mfg. Co., 4117 N Kilpatric Ave., Chicago 41, Ill.
Hunter Spring Co., 1 Spring Ave., Lansdale, Pa.
Huntington Land & Improvement Co., Standard Felt Co., 29 S Palm Ave., Alhambra, Calif.
Huron Automatic Screw Co., 1401 Water St., Port Huron, Mich.
Huron Forge & Machine Co., 9041 Alpine Ave., Detroit 4, Mich.
Hussey, C. G. & Co., 2850 2nd Ave., Pittsburgh 19, Pa.
Hydrawlik Co., 131-137 E 1st St., Roselle, N. J.
Hydroforming Co. of America, 4700 W Lawrence Ave., Chicago 31, Ill.
Hydrometals, Inc., Illinois Zinc Co., 2959 W 47th St., Chicago 32, Ill.
Hy-Level Screw Products Co., 2615 Scranton Rd., Cleveland 13, Ohio

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Ideal Can Co., 68 Vine St., Everett 49, Mass.
Ideal Metal Products Co., 4842 W Kinzie St., Chicago 44, Ill.
Ideal Plastics Corp., 184-10 Jamaica Ave., Hollis 7, N. Y.
Illinois Forge, Inc., 209 E 4th St., Rock Falls, Ill.
Illinois Iron & Bolt Co., Carpentersville, Ill.
Illinois Minerals Co., 807½ Washington Ave., Cairo, Ill.
Illinois Precise Casting Co., 903 N Spaulding Ave., Chicago 51, Ill.
Illinois Smelting & Refining Co., 3637 S Albany Ave., Chicago 32, Ill.
Illinois Tool Works, Shakeproof Div., St. Charles Rd., Elgin, Ill.
Imco Container Corp., 75th & Cleveland Sts., Kansas City, Mo.
Impax Inc., P. O. Box 5841, Ferguson 21, Mo.
Improved Seamless Wire Co., 775 Eddy St., Providence 5, R. I.
Imsande Screw Products Co., 3517 Cardiff Ave., Cincinnati 9, Ohio
Indar Corp., Indianapolis, Ind.
Independence Stove & Mfg. Co., Haywood & Cottage Sts., Independence, Mo.
Indiana Brass Co., Inc., P. O. Box 113, Frankfort, Ind.
Indiana Forge & Machine Co., 3468 Watling St., East Chicago, Ind.
Indiana Steel Products Co., Valparaiso, Ind.
Indiana Steel & Wire Co., Inc., 700 S Council St., Muncie, Ind.
Indium Corp. of America, 1676 Lincoln Ave., Utica, N. Y.
Indus Corp., Wheel & Bearing Div., 1125 E Georgia St., Indianapolis 2, Ind.
Industrial Chromium Corp., 109 Lyman St., Holyoke, Mass.
Industrial Electric, Inc., 3233 Magazine St., New Orleans 6, La.
Industrial Enterprises, Inc., Vinconnea Steel Div., Vinconnea, Ind.
Industrial Equipment Co., 115 Ohio St., Minster, Ohio
Industrial-Ferguson Foundry Corp., Route 22, Union, N. J.
Industrial Metal Protectives, Inc., 401 Homestead Ave., Dayton 8, Ohio
Industrial Mica Corp., 223 S Van Brunt St., Englewood, N. J.
Industrial Pipe & Supply Co., 5100 W 16th St., Cicero 50, Ill.
Industrial Plastic Fittings Co., 3891 W 150th St., Cleveland 11, Ohio
Industrial Plastics Corp., 816 W Beardsley Ave., Elkhart, Ind.
Industrial Precision Products, 325 N Hoyne Ave., Chicago 12, Ill.
Industrial Screw Machine Products Co., 1654 W 75th Pl., Chicago, Ill.
Industrial Synthetics Corp., 225 North Ave., Garwood, N. J.
Industrial Tectonics, Inc., 3686 Jackson Rd., Ann Arbor, Mich.
Ingalls Iron Works Co., 620 4th Ave., Birmingham, Ala.
Ingersoll-Rand Co., Phillipsburg, N. J.
Ingram-Richardson, Inc., 1450 Jefferson Rd., Frankfort, Ind.
Ingram-Richardson Mfg. Co., P. O. Box 191, Beaver Falls, Pa.
Inland Automatic, Inc., 1108 Jackson St., Omaha 8, Neb.
Inland Steel Co., 38 S Dearborn St., Chicago 3, Ill.
Inspiration Consolidated Copper Co., 25 Broadway, New York 4, N. Y.
Instrument Parts Corp., Snowden Ave. & Water St., Ossining, N. Y.
Instrument Specialties Co., Inc., 224-A Bergen Blvd., Little Falls, N. J. (Ad p 347)
Insulation Mfrs. Corp., 565 W Washington Blvd., Chicago 6, Ill.
Insulation Products Co., P. O. Box 5679, Pittsburgh 8, Pa.
Interchemical Corp., 67 W 44th St., New York 36, N. Y.
Angier Adhesives Div., 120 Potter St., Cambridge 42, Mass. (Ad p 221)
Finishes Div., 224 McWhorter St., Newark, N. J.
Interlake Mfg. Co., 13595 Helen Ave., Detroit 12, Mich.
International Balsa Corp., 94 Boyd Ave., Jersey City 4, N. J.
International Harvester Co., 180 Michigan Ave., Chicago, Ill.
International Nickel Co., Inc., 67 Wall St., New York 5, N. Y. (Ads pp 77, 125)
International Optical Co., Inc., 47 Urban Ave., Westbury, L. I., N. Y.
International Paper Co., Long-Bell Div., Longview, Wash.
International Powder Metallurgy Co., Inc., 439 Main St., Ridgeway, Pa.
Investment Castings Co., 60 Brown Ave., Springfield, N. J.
Iowa Malleable Iron Co., 9th & Kirkwood Sts., Fairfield, Iowa
Irvington Form & Tank Corp., 20 Vesey St., New York 7, N. Y.
Irwin Foundry & Mine Car Co., Industrial & Furnace Car Div., Box 311, Irwin, Pa.
Isaacson Iron Works, 8531 E Marginal Way, Seattle 14, Wash.
Isocyanate Products, Inc., 900 Wilmington Rd., New Castle, Del.
Iten Fibre Co., P. O. Box 20, Ashtabula, Ohio

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Jackson Auto Radiator, 1515 Altgeld St., Chicago 14, Ill.
Jackson Steel Products, Inc., 32 Rodney St., Brooklyn 11, N. Y.
Jackson-Wheeler Metals Service, Inc., 270 Georgia Ave., Brooklyn, N. Y.
Jamestown Malleable Iron Corp., Tiffany Ave., Jamestown, N. Y.
Jamestown Paint & Varnish Co., Jamestown, Pa.
Janney Cylinder Co., 7401 State Rd., Philadelphia 36, Pa.
Janson Industries, Inc., 268 Norman Ave., Brooklyn 22, N. Y.
Jarco Metal Products, Portland Ave., Westbury, L. I., N. Y.
Jarl Extrusions, Inc., 400 W Commercial Ave., East Rochester, N. Y. (Ad p 360)
Jasco Aluminum Products Corp., New Hyde Park, N. Y.
Jasper Lacquer Co., Inc., Vine St., Jasper, Ind.
Jeannette Shade & Novelty Co., N 4th, Jeannette, Pa.
Jelliff, C. O. Corp., Southport, Conn.
Jelrus Precision Casting Corp., 136 W 52nd St., New York 19, N. Y.
Jema Chemical & Supply Co., 190 South St., Newark, N. J.
Jet Components, Inc., 3142 San Fernando Rd., Los Angeles, Calif.
Jet Specialties Co., Inc., 941 N Eastern Ave., Los Angeles, Calif.
Jobbins, William F. Inc., Aurora, Ill.
Johns-Manville Corp., Dutch Brand Div., 22 E 40th St., New York 16, N. Y.

In contacting suppliers, please mention the Materials Selector

Johnson Bronze Co., 500 S Mill St., New Castle, Pa.
Johnson Glass & Plastic Corp., 5248 Elston Ave., Chicago 30, Ill.
Johnson Metal Hose, Inc., 10 Sperry St., Waterbury 20, Conn.
Johnson Plastic Corp., Box 312, Chagrin Falls, Ohio
Johnson Rubber Co., 111 Vine St., Middlefield, Ohio
Johnson Steel & Wire Co., Inc., 53 Wiser Ave., Worcester 1, Mass.
Johnstone Foundries, Inc., Grove City, Pa.
Jolens Metal Products Co., 224 Sussex Ave., Newark 4, N. J.
Jones & Laughlin Steel Corp., 3 Gateway Center, Pittsburgh 30, Pa. (Ads pp 76, 323)
Jones Metal Products Co., West Lafayette, Ohio
Jones-Dabney Co., 1481 S 11th St., Louisville, Ky.
Jordan Co., 51st & Merrimac Ave., Chicago 38, Ill.
Jordan Machine Products, Inc., 3611 St. Aubin Ave., Detroit 7, Mich.
Jordan-Rogers Co., 640 N Cypress, Orange, Calif.
Joslyn Mfg. & Supply Co., Wm. E. Pratt Mfg. Co. Div., 18 Henderson Ave., Joliet, Ill.
Joymont Plastics, Inc., 710 S State St., Girard, Ohio
Judd Industries, Inc., 3148 W 32nd St., Cleveland 9, Ohio
Judsen Rubber Works, Inc., 4107 W Kinzie St., Chicago 24, Ill.

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K-D Mfg. Co., 435 Shaffer St., Cleburne, Texas
K & L Plating Co., 535 E Mifflin St., Lancaster, Pa.
KSH Plastics, Inc., Hwy. 30, High Ridge, Mo.
Kaiser Aluminum & Chemical Sales, Inc., 919 Michigan Ave., Chicago 11, Ill.
Kaiser Metal Products, Inc., Bristol, Pa.
Kanawha Mfg. Co., Charleston, W. Va.
Kano Laboratories, 1000 S Thompson Lane, Nashville 11, Tenn.
Kansas City Hay Press Co., 801 Weeswether Rd., Kansas City 5, Mo.
Kawneer Co., Mill Products Div., St. Charles, Ill.
Kay-Bee Machine Products Co., 2776 S 34th St., Milwaukee 15, Wis.
Kay-Brunner Steel Products, Inc., 999 Meridian Ave., Alhambra, Calif.
Kaykor Industries, Inc., Yardville, N. J.
Keasbey & Mattison Co., 1956 Butler Ave., Ambler, Pa.
Keen Foundry Co., Inc., E Main & E Jerr Sts., Griffith, Ind.
Kees, F. D. Mfg. Co., 700 Park St., Beatrice, Neb.
Kelly Foundry Co., 1704 Wharton St., Pittsburgh 3, Pa.
Kelsey-Hayes Co., Utica Drop Forge & Tool Div., 2415 Whitesboro St., Utica, N. Y.
Kendall Co., Polyken Sales Div., 309 W Jackson Blvd., Chicago, Ill.
Kendall Mills, Inc., Walpole, Mass.
Kensico Tube Co., Inc., Hubbell & R. R. Aves., Mt. Kisco, N. Y.
Kenmore Machine Products, Inc., 15 Depew Ave., Lyons, N. Y.
Kennametal, Inc., Lloyd Ave., Latrobe, Pa.
Kennecott Copper Corp., 161 E 42nd St., New York, N. Y.
Kennedy Automatic Products, Inc., 406 S Linden St., Marshall, Mich.
Kenosha Automatic Products Co., 3919 13th Ave., Kenosha, Wis.
Kent Castings Corp., 200 Garden St. SE, Grand Rapids 7, Mich.
Keolyn Plastics, Inc., 2731 N Pulaski Rd., Chicago 39, Ill.
Kepec Chemical Corp., P. O. Box 782, 1454 N 4th St., Milwaukee 1, Wis.
Kerr, R. W. Plastic Co., 220 S Burlington Ave., Hastings, Neb.
Kerr-Lakeside Industries, Inc., 21850 St. Clair Ave., Cleveland 17, Ohio
Kewaunee Engineering Corp., N Main St., Kewaunee, Wis.
Keystone Carbon Co., 1935 State St., St. Marys, Pa.
Keystone Drawn Steel Co., Main & Bridge Sts., Spring City, Pa.
Keystone Forging Co., Northumberland, Pa.
Keystone Plastics, Inc., 2331 Morris Ave., Union, N. J.
Keystone Refining Co., Inc., 4821-31 Garden St., Philadelphia 37, Pa.
Keystone Steel & Wire Co., Peoria 7, Ill.
Kickhaefer Mfg. Co., 901 S 2nd St., Milwaukee 4, Wis.
Kidd Drawn Steel Co., Aliquippa, Pa.
King, Alfred B. Co., Devine St., North Haven, Conn.
King Laboratories, Inc., 127 Solar St., Syracuse 3, N. Y.
King-Seely Corp., Central Specialty Div., 720 Norris St., Ypsilanti, Mich.
Kingsport Foundry & Mfg. Corp., E Sullivan & Main Sts., Kingsport, Tenn.
Kipp & Co., Inc., 3401 S Hanover St., Baltimore 25, Md.
Kirchhof Patent Co., Inc., Dietze Bldg., 60-64 Union St., Newark 5, N. J.
Kirk, Morris P. & Son, Inc., 2700 S Indiana St., Los Angeles 23, Calif.
Kleiner Metal Specialties, Inc., P. O. Box 185, Dunellen, N. J.
Kling Metal Spinning & Stamping Co., 245-247 Centre St., New York 13, N. Y.
Klinizing, A. F. Co., Inc., 921A S 2nd St., Milwaukee 4, Wis.
Klise Mfg. Co., Inc., 50 Cottage Grove St., Grand Rapids 2, Mich.
Knapp Mills, Inc., 23-17 Borden Ave., Long Island City 1, N. Y.
Knight, Maurice A., 171 Kelly Ave., Akron 6, Ohio
Knoedler Chemical Co., 651 High St., Lancaster, Pa.
Knowlton Bros., Inc., 215 Factory, Watertown, N. Y.
Knox Porcelain Corp., 2706 Mynders Ave., Knoxville 1, Tenn.
Koehring Co., Milwaukee, Wis.
Kohn Engineering Corp., 8830 S Telegraph Rd., Taylor Center, Mich.
Kolcast Industries, Inc., 16601 Euclid, Cleveland, Ohio
Koller Craft Plastic Products, Inc., Fenton, Mo.
Kopp Glass, Inc., 2108 Palmer St., Pittsburgh, Pa.
Koppers Co., Inc., Chemical Div., Koppers Bldg., Pittsburgh 19, Pa.
Koster-Keunen Mfg. Co., Inc., Bourne Blvd., Sayville, N. Y.
Koven, L. O. & Bro., Inc., 154 Ogden Ave., Jersey City 7, N. J.
Koven Fabricators, Inc., 90 E Dickerson St., Dover, N. J.
Kover, John R. Mfg. Co., Inc., Bridge Sq., Anoka, Minn.
Kraloy Plastics Pipe Co., Inc., 4710-20 E Washington Blvd., Los Angeles 22, Calif.
Kramer, C. P. Co., 9230 W Belmont Ave., Franklin Park, Ill.
Kramer, H. & Co., Ajax Metal Div., 46 Richmond St., Philadelphia 23, Pa.
Kroh Wagner, 2331-41 N Crawford Ave., Chicago 39, Ill.
Krone, Paul Die Casting Co., 1811 N Kostner Ave., Chicago 39, Ill.
Kropp Forge Co., 5301 W Roosevelt Rd., Chicago 50, Ill.
Krueger Fabricating Co., Inc., 257 W Badger Rd., Madison 5, Wis.
Krueger & Hudepohl, Inc., 1041 Evans St., Cincinnati 4, Ohio
Kuhn & Jacob Molding & Tool Co., 1200 Southard Ave., Trenton 8, N. J.
Kurz-Kasch Inc., 1421 S Broadway, Dayton 1, Ohio
Kuss, R. L. & Co., Inc., 739 Foulke Ave., Findlay, Ohio
Kutztown Foundry & Machine Corp., Kutztown, Pa.
Kwikset Powdered Metal Products, 516 W Santa Ana St., Anaheim, Calif.

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L.O.F. Glass Fibers Co., 1810 Madison Ave., Toledo 1, Ohio
Corrulux Div., P. O. Box 20026, Houston, Tex.
La France Precision Casting Co., 2002 S 29th St., Philadelphia 45, Pa.
La Porte Foundry Co., 301 Truesdell Ave., La Porte, Ind.
La Salle Steel Co., P. O. Box 6800-A, Chicago 80, Ill.
Laclede Steel Co., Arcade Bldg., 812 Olive St., St. Louis, Mo.
Laconia Malleable Iron Co., 71 Water St., Laconia, N. H.
Lacquer & Chemical Corp., 214 40th St., Brooklyn 32, N. Y.
Lacquer Products Inc., 9001 Kinsman Rd., Cleveland 4, Ohio
Ladish Co., 5481 Packford Ave., Cudahy, Wis.
Lake Chemical Co., 3052 W Carroll Ave., Chicago 12, Ill.
Lake City Malleable Co., 5000 Lakeside Ave., Cleveland 14, Ill.
Lake Erie Foundry Co., 143 Fillmore Ave., Buffalo 10, N. Y.
Lake Erie Foundry Co., Inc., 302 Penn Ave., Girard, Pa.
Lake Mfg. Corp., 1070 East St., New Britain, Conn.
Lakeland Industries, Isle, Minn.
Lakeside Bronze, Inc., 90 Arthur St., Buffalo 7, N. Y.
Lakeside Malleable Castings Co., Racine, Wis.
Lakeview Forge Co., 1725 Pittsburgh Ave., Erie, Pa.
Lakewood Metal Products, Inc., 39 Cherry Ave., Waterbury 20, Conn.
Laminated Plas-Tex Corp., 1427 W North St., Springfield, Ohio
Laminated Shim Co., 1600 Union St., Glenbrook, Conn. (Ad p 335)
Lamson Products Co., 1228 Poplar Pl., Seattle 44, Wash.
Lamtex Industries, Inc., 51 State St., Westbury, L. I., N. Y.
Lancaster Glass Corp., Lancaster, Ohio
Lancaster Malleable Castings Co., 1170 Lititz Ave., Lancaster, Pa.
Landau, J. & Co., Inc., Washington Ave., Carlstadt, N. J.
Lang-Scharmann & Co., 206 W 1st St., Marshfield, Wis.
Langsenkamp, F. H. Co., South & Harmon Sts., Indianapolis, Ind.
Langsenkamp-Wheeler Brass Works Inc., 1234 Shelby St., Indianapolis, Ind.
Lansdale Porcelain Enamel Corp., Lansdale, Pa.

Larkin Specialty Mfg. Co., 915 Linden Ave., South San Francisco, Calif.
Larson, Charles E. & Sons, Inc., 2665 N Keeler Ave., Chicago 22, Ill.
Larson Tool & Stamping Co., Olive St., Attleboro, Mass.
Latrobe Steel Co., Latrobe, Pa.
Lattimer Foundry & Machine Co., Lattimer Mines, Pa.
Lattner Bros. Machining Co., 650 E Troy, Ferndale 20, Mich.
Latwaitis, Ernest A., 102-09 Remsen Pl., Howard Beach 14, N. Y.
Lavin R. & Sons, Inc., 3426 S Kedzie Ave., Chicago 23, Ill.
Lawrence, L. Co., Inc., 292 Halsey St., Newark 2, N. J.
Lawrence Copper & Bronze Co., W New Castle St., Zilenpole, Pa.
Lawrence Laboratory, 1668 Euclid St., Santa Monica, Calif.
Lawrenceville Screw Co., 4920 Harrison St., Pittsburgh 1, Pa.
Laystrom Mfg. Co., 2001-17 N Parkside Ave., Chicago 39, Pa.
Leach & Garner Co., Industrial Div., Leach & Garner Bldg., Attleboro, Mass. (Ad p 327)
Leader Iron Works, Inc., 2100 N Jasper St., Decatur, Ill.
Lebanon Steel Foundry, 1st Ave. & E Lehmen St., Lebanon, Pa. (Ad p 313)
Lee Bros. Foundry Co., Inc., P. O. Box 231, Anniston, Ala.
Lee Rubber & Tire Corp., Hector St., Conshohocken, Pa.
Leed, H. A. Co., 1685 Diswell Ave., Hamden, Conn.
Lehigh, Inc., 1500 Lehigh Dr., Easton, Pa.
Leitelt Bros., Inc., 7721 S Chicago Ave., Chicago 19, Ill.
Lenape Hydraulic Pressing & Forging Co., Box 536, West Chester, Pa. (Ad p 341)
Lerner Plastics, Inc., 502 South Ave., Garwood, N. J.
Lester Castings, Inc., Cannon & Aurora Rds., Bedford Heights, Ohio
Levinson Steel Co., S 20th & Wharton St., Pittsburgh 3, Pa.
Lewin-Mathes Co., 1111 Chouteau Ave., St. Louis 2, Mo.
Lewis, J. P. Co., Plastic Products Div., Beaver Falls, N. Y.
Lewis & Saunders, Lakeport, N. H.
Lewis Welding & Engineering Corp., 100 Northfield Rd., Bedford, Ohio
Lewistown Foundry & Machine Co., 16 Elizabeth St., Lewistown, Pa.
Libbey-Owens-Ford Glass Co., 1808 Madison Ave., Toledo, Ohio.
Liepsner & Co., 1513 Oak St., Kansas City 8, Mo.
Light Metals Corp., 1211 Monroe Ave. NW, Grand Rapids, Mich.
Light Metals, Inc., 1100 E 24th St., Indianapolis, Ind.
Lignum-Vitae Products Corp., 98 Boyd Ave., Jersey City 4, N. J.
Lincoln Electric Co., 22777 St. Clair Ave., Cleveland, Ohio
Lincoln Foundry, 1803 Delavan St., Lincoln, Ill.
Lincoln Foundry Corp., 2525 E 49th St., Los Angeles 58, Calif.
Lincoln Iron Works, Rutland, Vt.
Lincoln Machine Parts Corp., 732 E 144th St., New York 54, N. Y.
Lincoln Mfg. Co., Inc., 2617 W Fletcher St., Chicago 18, Ill.
Lincoln Steel Corp., 315 W 9th St., Lincoln 1, Neb.
Lindell Drop Forge Co., 2830 S Logan Blvd., Lansing 3, Mich.
Linden & Co., Inc., 80 Baker St., Providence 5, R. I.
Linderme Tube Co., 1500 219th St., Cleveland 17, Ohio
Lindsay Chemical Co., 264 Ann St., West Chicago, Ill.
Link-Belt Co., 220 S Belmont Ave., Indianapolis 6, Ind.
Litemetal Dicast Inc., 1927 Wildwood Ave., Jackson, Mich.
Lithcote Corp., 5000 W Lake St., Melrose Park, Ill.
Lithium Corp. of America, Inc., 2690 Rand Tower, Minneapolis 2, Minn. (Ad p 129)
Littite Foundries, Inc., 2431 Conners St., Port Huron, Mich.
Little Falls Alloys, inc., 189 Caldwell Ave., Paterson, N. J. (Ad p 358)
Littlestown Hardware & Foundry Co., Inc., Charles St., Littlestown, Pa.
Livingston-Tyler Products, 501 N 5th St., Hamilton, Ohio
Lloyd & Scott Brass Foundry, Inc., 2206 Tatnall St., Wilmington 99, Del.
Lock Joint Tube Co., 1400 Riverside Dr., South Bend, Ind.
Locke Machine Co., 971 E 63rd St., Cleveland 3, Ohio
Lockhart Iron & Steel Co., River Ave., McKees Rocks, Pa.
Lockport Mfg. Co., 1102 Collins St., Joliet, Ill.
Lockport Steel Fabricators, Inc., P. O. Box 67, Lockport, Ill.
Lockrey-Fater Corp., 38-13 10th St., Long Island City 1, N. Y.
Lodge Mfg. Co., R.R. & 6th, South Pittsburgh, Pa.
Loeffler, J. M. Co., Machine & Brass Works, 149 N 4th St., Philadelphia 6, Pa.
Loewenthal Metals Corp., 947 Cullerton St., Chicago 8, Ill.
Logo, Inc., 12933 S Stoney Island Ave., Chicago 33, Ill. (Ad p 270)
Long Beach Iron Works, 2100 W Anaheim St., Long Beach 13, Calif.
Longview Paint & Varnish Co., 1203 California Way, Longview, Wash.
Lorain Automatic Screw Machine Co., Inc., 218 Connecticut, Lorain, Ohio
Lorain Brass Co., 639 Broadway, Lorain, Ohio
Lord Chemical Co., 2068 S Queen St., York, Pa.
Los Angeles Steel Casting Co., 6100 S Boyle Ave., Los Angeles 58, Calif.
Loven Chemical of California, 244 S Pine St., Newhall, Calif.
Lowe Bros. Co., 424 E 3rd St., Dayton 2, Ohio
Lubenow, Arthur Co., 2015 S Kinnickinnic Ave., Milwaukee 7, Wis.
Lukens Steel Co., Coatesville, Pa.
Lumb Woodworking Co., Inc., 61 Main St., Poughkeepsie, N. Y.
Lumen Bearing Co., 197 Linthrop St., Buffalo 12, N. Y.
Luminous Resins, Inc., 180 W Washington St., Chicago 2, Ill.
Lundberg Screw Products Co., 2101 W Willow St., Lansing 4, Mich.
Lunn Laminates, Inc., Oakwood & W 11th Sts., Huntington Station, N. Y.
Luria Engineering Co., 1745 Easton Ave., Bethlehem, Pa.
Lustra-Cite Industries, Inc., 331 Kent Ave., Brooklyn 11, N. Y.
Lux Clock Mfg. Co., Inc., 95 Johnson St., Waterbury 20, Conn.
Luzerne Rubber Co., Muirhead Ave., Trenton 7, N. J.
Lyndon Machine Products Co., Inc., 18564 Fitzpatrick Ave., Detroit 28, Mich.
Lynn, Gary Co., 926 York St., Cincinnati 14, Ohio

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M & S Mfg. Co., 220 Main St., Hudson, Mich.
Mass & Waldstein Co., 2121 McCarter Hwy., Newark 4, N. J.
Macaulay, H. C. Foundry Co., 811 Carlton St., Berkeley 10, Calif.
Machine Products Corp., 425 Hollier Ave., Dayton 3, Ohio
Machinery Forging Co., 5430 Hamilton Ave., Cleveland 14, Ohio
Machinery Products Co. of Lancaster, 317 E Fulton St., Lancaster 10, Pa.
Machinery Products Corp., 2020 N Major Ave., Chicago 39, Ill.
Mac-It Parts Co., 275 E Liberty St., Lancaster, Pa.
MacKenzie Walton Co., 478 Pawtucket Ave., Pawtucket, R. I.
Macwhyte Co., 2906 14th Ave., Kenosha, Wis.
Madison Foundry Co., 935 Addison Rd., Cleveland 3, Ohio
Madison-Kipp Corp., 217 Waubesa St., Madison 4, Wis.
Magic Chemical Co., 121 Crescent St., Brockton 2, Mass.
Magic Iron Cement Co., 5403 Bower Ave., Cleveland 27, Ohio
Magirl Foundry & Furnace Co., 413 E Oakland Ave., Bloomington, Ill.
Magline, Inc., 1960 Mercer St., Pinconning, Mich.
Magna Mfg. Co., Inc., 4th Ave., Haskell, N. J.
Magnesium Co. of America, 5222 Indianapolis Blvd., East Chicago, Ill.
Magnetic Powders, Inc., Fairview Ave., Johnsonburg, Pa.
Magnode Products, Inc., Extrusion Div., P. O. Box 292, Trenton, Ohio
Mahon, R. C. Co., 6565 E 8 Mile Road, Detroit 34, Mich.
Main Screw Machine Products, Inc., 58 Lafayette St., Waterbury, Conn.
Majestic Stamping Co., 9310 Hubbell Ave., Detroit 28, Mich.
Makepeace, D. E. Co., Attleboro, Mass.
Mallory, P. R. & Co., Inc., 3033 E Washington, Indianapolis 6, Ind.
Mallory-Sharon Titanium Corp., 980 Warren Ave., Niles, Ohio (Ad p 133)
Malone Bronze Powder Works, Inc., Malone, N. Y.
Malone Metal Powders, Inc., 220 W 42nd St., New York 36, N. Y.
Mansfield Brass & Aluminum Corp., 287 N Diamond St., Mansfield, Ohio
Mantel Screw Products Co., 3200 W Vliet St., Milwaukee 8, Wis.
Manufacturers Corp., 104 Ausdale Ave., Mansfield, Ohio
Manufacturers & Fabricators, Inc., Filbert St., Elyria, Ohio
Manufacturers Iron Foundry, Inc., 785 Union Ave., Bridgeport, Conn.
Marblette Corp., 37-31 30th St., Long Island City 1, N. Y.
Markal Co., 3052 W Carroll Ave., Chicago 12, Ill.
Marko Engineering Co., Inc., 801 Herring Ave., Charlotte 1, N. C.
Marquette Mfg Co., Inc., 307 E Hennepin Ave., Minneapolis, Minn.
Marquette Metal Products Co., 1145 Galewood Dr., Cleveland 10, Ohio
Marshall Car Wheel & Foundry Co., Inc., 605 Greenwood Ave., Marshall, Tex.
Martin Rubber Co., Inc., 156 Broadway, Long Branch, N. J.
Martin Varnish Co., 900 W 49th St., Chicago 9, Ill.
Masco Screw Products Co., 12825 Ford Rd., Dearborn, Mich.

Addresses of Suppliers

Masland Duraleather Co., Amber & Willard Sts., Philadelphia 34, Pa.
Mason Envelope Co., Inc., 536 Broadway, New York 12, N. Y.
Masonite Corp., P. O. Box 268, Ukiah, Calif.
Massachusetts Screw Mfg. Co., 9 W 3rd St., South Boston 27, Mass.
Master Bronze Powder Co., Inc., 538-548 W State St., Calumet City, Ill.
Master Chrome Service, Inc., 5709 Herman Ave., Cleveland 2, Ohio
Masury, John W. & Son, Inc., Bayard & Severn Sts., Baltimore 30, Md.
Matthiessen & Hegeler Zinc Co., 9th & Sterling Sts., LaSalle, Ill.
Maumee Machine & Tool Corp., 2501 Lagrange St., Toledo 8, Ohio
Maynard Mfg. Co., 22755 Shakespeare Ave., East Detroit, Mich.
Mayon Plastics, 415 17th Ave. N, Hopkins, Minn.
Mayville Metal Products Co., 104 Highland St., Mayville, Wis.
McCarter Iron Works, Inc., Norristown, Pa.
McDanel Refractory Porcelain Co., 2929 Main St., Buffalo 14, N. Y. (Ad p 242)
McDowell Mfg. Co., 301 Stanton Ave., Pittsburgh 9, Pa.
McGean Chemical Co., 1040 Midland Bldg., 101 Prospect Ave. NW, Cleveland 15, Ohio
McInnes Steel Co., 441 E Main St., Corry, Pa.
McKay Co., 481 McKay Bldg., Pittsburgh, Pa.
McKinney Mfg. Co., 1715 Liverpool St., Pittsburgh 33, Pa.
McLanahan & Stone Corp., 200 Wall St., Hollidaysburg, Pa.
McLouth Steel Corp., 300 S Livernois Ave., Detroit 17, Mich.
McMahon Bros. Machine Works, Inc., 3200 S 61st Court, Cicero 50, Ill.
McMath-Axilrod Corp., 628 Third Ave., Dallas, Tex.
McNally Pittsburg Mfg. Corp., Drawer D, Pittsburg, Kan.
Meaden Screw Products Co., 3010 S Kilbourn Ave., Chicago 23, Ill.
Mearl Corp., 124 E 40th St., New York, N. Y.
Measuregraph Co., 4245 Forest Park Blvd., St. Louis 8, Mo.
Mechanical Art Works, Inc., 96-98 Monroe St., Newark 5, N. J.
Mechanical Felt & Textiles Co., 50 W 18th St., Weehawken, N. J.
Mechanical Leathers, Inc., 2204 E Butler St., Philadelphia 37, Pa.
Mechanical Plating Co., 1500-26 W Hubbard St., Chicago 22, Ill.
Mechanical Rubber Products Co., Warwick, N. Y.
Mechanical Steel Tubing Corp., 500 Barry St., New York 59, N. Y.
Medico Industries, Inc., 11-13 Tompkins St., Pittston, Pa.
Meehanite Metal Corp., 714 North Ave., New Rochelle, N. Y. (Ad pp 354, 355)
Meeker Foundry Co., Newark 4, N. J.
Meier Screw Products & Mfg. Co., 19361 Sherwood Ave., Detroit, Mich.
Melco Wire Products, 4407 San Fernando Rd., Glendale 4, Calif.
Melling Forging Co., 1709 Thompson St., Lansing 3, Mich.
Menardi & Co., 1222 E Grand Ave., El Segundo, Calif.
Mengel Co., P. O. Box 660, Louisville 1, Ky.
Merit Screw Machine Products Co., 4847 W Lake St., Chicago 44, Ill.
Merit Specialties Co., Inc., 203-205 E Davis St., St. Louis 11, Mo.
Merix Chemical Co., 1021 E 55th St., Chicago 15, Ill.
Merkin, M. J. Paint Co., Inc., 1441 Broadway, New York, N. Y.
Merrimac Brass Co., 22 High St., Merrimac, Mass.
Merriman Bros., Inc., 185 Amory St., Boston 30, Mass.
Merz Machine & Tool Works, 920 N Main St., Crown Point, Ind.
Mesa Plastics Co., 11751 Mississippi St., Los Angeles 25, Calif.
Metal Coating Corp., 1217 W 37th St., Chicago 9, Ill.
Metal Finishers, Inc., 78 S Franklintown Rd., Baltimore 23, Md.
Metal Forming Corp., 1937 Sterling Ave., Elkhart, Ind.
Metal Goods Corp., 6211 Cedar Springs Rd., Dallas 35, Tex.
Metal Hydrides, Inc., 12 Congress St., Beverly, Mass.
Metal Mold Magnesium Corp., 95 Hamilton St., Cedarburg, Wis.
Metal Parts & Stamping Co., 1120 Eastern Ave., Cincinnati, Ohio
Metal Powder Products, Inc., P. O. Box 189-C, Logan, Ohio
Metal Textile Corp., 1st Ave., E, Roselle, N. J.
Metal & Thermit Corp., Rahway, N. J.
Metal Trims, Inc., Livingston Rd., Jackson, Miss.
Metal-Cladding, Inc., North Tonawanda, N. Y.
Metallizing Co. of America, 3520 W Carroll Ave., Chicago, Ill.
Metallizing Co. of Los Angeles, 1233 S Boyle Ave., Los Angeles 23, Calif.
Metallizing Engineering Co., Inc., 1101 Prospect Ave., Westbury, L. I., N. Y. (Ads pp 126, 266)
Metallurgical Products Co., 35th & Moore Sts., Philadelphia, Pa.
Metals & Controls Corp., General Plate Div., 50 Forest St., Attleboro, Mass.
Metals Disintegrating Co., Inc., P. O. Box 290, Elizabeth, N. J.
Metalweld, Inc., Protective Coating Div., Scotts Lane & Abbottsford Ave., Philadelphia, Pa.
Metaplast Process, Inc., 34-51 56th Ave., Woodside, New York, N. Y.
Met-L-Wood Corp., 6755 W 65th St., Chicago 38, Ill.
Meyer, J. & Sons, Inc., 4321 N 4th St., Philadelphia 40, Pa.
Mica Fabricating Co., 53 Central Ave., Rochelle Park, N. J.
Mica Insulator Co., Schenectady 1, N. Y.
Michelman Chemicals, Inc., 6316 Wiehee Rd., Cincinnati, Ohio
Michigan Chrome & Chemical Co., 8615 Grinnell Ave., Detroit 5, Mich.
Michigan Leather Products Co., 6307 E Lafayette Ave., Detroit 7, Mich.
Michigan Powdered Metal Product Co., Inc., 456 E Cady St., Northville, Mich.
Michigan Wire Cloth Co., 2100 Howard St., Detroit 16, Mich.
Micro Metallic Corp., 30 Sea Cliff Ave., Glen Cove, N. Y.
Micro Products Corp., 4116-18 Olive St., St. Louis 8, Mo.
Micro-Metals Co., 52 E Montecito Ave., Sierra Madre, Calif.
Midland Adhesive & Chemical Corp., 2600 Goodrich St., Ferndale, Mich.
Midland Industrial Finishes Co., East Water St., Waukegan, Ill.
Midland Paint & Varnish Co., 3801 E 91st St., Cleveland 5, Ohio
Midland Pipe & Supply Co., 2829 S 61st St., Cicero 50, Ill.
Mid-States Rubber Products, Inc., 221 E Maxwell Ave., Evansville, Ind.
Midvale-Heppenstall Co., Nicetown, Philadelphia 40, Pa.
Midwest Mfg. Co., 24 Allen St., St. Louis 19, Mo.
Midwest Molding & Mfg. Co., Gurnee, Ill.
Midwest Piping Co., Inc., 2nd & Barry Sts., St. Louis 4, Mo.
Midwest Plastic Products Co., 1801 Chicago Rd., Chicago Heights, Ill.
Midwest Screw Products, Inc., 1641 Coit Ave., East Cleveland 12, Ohio
Mid-West Screw Products Co., 3662 Park Ave., St. Louis 10, Mo.
Midwest Sintered Products, 13605 S Halsted St., Chicago 27, Ill.
Mid-West Wire Products Co., Inc., 2555 Fenkell Ave., Detroit 38, Mich.
Midwestern Foundries, Inc., 614 E Quincy, Garrett, Ind.
Milford Automatics, Inc., 1553 Boston Post Rd., Milford 15, Conn.
Milford Rivet & Machine Co., 857 Bridgeport Ave., Milford, Conn.
Milled Screw Products Co., 2016-2026 W Lake St., Chicago 12, Ill.
Miller Co., Rolling Mill Div., 99 Centre St., Meriden, Conn.
Millers' Brass Fitting Co., Inc., 30 Main St., Brooklyn 1, N. Y.
Milwaukee Aluminum & Brass Foundry, 643 S 2nd St., Milwaukee 4, Wis.
Milwaukee Die Casting Co., 4132 N Holton St., Milwaukee 12, Wis.
Milwaukee Forge & Machine Co., 1532 E Oklahoma Ave., Milwaukee 7, Wis.
Milwaukee Machine Products Co., 3889 N 1st St., Milwaukee 12, Wis.
Milwaukee Stamping Co., 800-S 72nd St., Milwaukee 14, Wis.
Milwaukee Valve Co., 2375 S Burrell St., Milwaukee, Wis.
Minimax Co., 5905 N Clark St., Chicago 26, Ill.
Minneapolis Electric Steel Castings Co., 3800 NE 5th St., Minneapolis 21, Minn.
Minneapolis Honeywell Regulator Co., 2753 4th Ave. S, Minneapolis 8, Minn.
Minnesota Mining & Mfg. Co., 900 Bush Ave., St. Paul 6, Minn.
Adhesives & Coatings Div., 411 Piquette Ave., Detroit 2, Mich.
Irvington Varnish & Insulation Div., Irvington, N. J.
Mica Insulator Div., 1219 California St., Denver, Colo.
Minnesota Platon Corp., Hwy. 23, Northeast Pipestone, Minn.
Minnesota Rubber & Gasket Co., 3630 Wooddale Ave., Minneapolis 16, Minn.
Misco Precision Casting Co., 116 W Gibbs, Whitehall, Mich.
Misner Corp., 940 N 23rd St., Omaha 2, Neb.
Missouri Boiler & Sheet Iron Works, 23rd & Papin Sts., St. Louis 3, Mo.
Missouri Paint & Varnish Co., 5125 N 2nd St., St. Louis 7, Mo.
Mitchel & Scott Machine Co., Inc., 1841 Ludlow Ave., Indianapolis 7, Ind.
Mitchell-Bradford Chemical Co., Wampus Lane, Milford, Conn.
Mobay Chemical Co., 1901 S 2nd St., St. Louis 4, Mo. (Ad p 216)
Mobile Paint Mfg. Co., 854 S Conception St., Mobile 9, Ala.
Model Brass Co., Inc., 232-40 E Decatur St., Decatur, Ill.
Modern Brass Foundry & Mfg. Co., 157 Thurman St., Columbus 6, Ohio
Modern Plastics Corp., 121-129 S Hancock Ave., Freeport, Ill.
Modern Plating Corp., Hancock Ave. & Album St., Freeport, Ill.

Bold face indicates supplier advertises in this issue

Modern Screw Products Co., 2307 N 9th St., St. Louis 6, Mo.

Molded Fiber Glass Co., 4421 Benefit Ave., Ashtabula, Ohio (Ad p 348)

Molded Products Co., Inc., Route 5, Burlington, Wis.
Moldex, 745 5th Ave., New York 22, N. Y.
Monarch Aluminum Mfg. Co., 9205 Detroit Ave., Cleveland 2, Ohio
Monarch Products Co., Leske Stamping Div., 1259 E 1st St., Monroe, Mich.
Monarch Tool & Mfg. Co., 105 E 4th St., Covington, Ky.
Mono-Sol Corp., 407 County Line Rd., Gary, Ind.
Monroe Co., Inc., 10703 Quebec Ave., Cleveland 16, Ohio
Monroe, Lederer & Taussig, Inc., 606 N American St., Philadelphia 23, Pa.
Monsanto Chemical Co., Plastics Div., 600 Monsanto Ave., Springfield, Mass.
Montague Machine Co., 15th St., Turners Falls, Mass.
Monteath, J. H. Co., 2500 Park Ave., New York 51, N. Y.
Moody Machine Products Co., Inc., 42 Dudley St., Providence 5, R. I.
Moore, George W. Inc., 100 Beaver St., Waltham 54, Mass.
Moore Dry Dock Co., Adeline St., Oakland 23, Calif.
Morganite, Inc., 3320 48th Ave., Long Island City 1, N. Y.
Morningstar, Nicol, Inc., Paisley Products, Inc. Div., 630 W 51st St., New York 19, N. Y.
Morrison Steel Products, Inc., 601 Amherst St., Buffalo 7, N. Y.
Morrisville Foundry Co., Inc., Morrisville, Vt.
Morse, Fred W. Co., 309 S Main St., Providence 3, R. I.
Mosinee Paper Mills Co., Mosinee, Wis.
Mt. Vernon Die Casting Corp., Southfield Ave., Stamford, Conn.
Muehlstein, H. & Co., Inc., 60 E 42nd St., New York 17, N. Y.
Mueller Brass Co., 1925 Lapeer Ave., Port Huron, Mich.
Mueller Machine Products, Inc., 3807 S Packard Ave., Cudahy, Wis.
Muncie Malleable Foundry Co., E Highland Ave., Muncie, Ind.
Muncie Metal Spinning Inc., 3000 S Hackley St., Muncie, Ind.
Murdock Mfg. Co., 4056 Del Rey Ave., Venice, Calif.
Murray Tube Works, Inc., P. O. Box 476, Elizabeth, N. J.
Muskegon Piston Ring Co., Gardner St., Sparta, Mich.
Sparta Foundry Div., Sparta, Mich.

Mycalex Corp. of America, 125 Clifton Blvd., Clifton, N. J. (Ad pp 184, 185)

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Naige Co., Inc., 625 S Goodman St., Rochester 2, N. Y.
Napoleon Products Co., 410 Filmore St., Napoleon, Ohio
Narragansett Boiler Works, Inc., 614 S Main St., Providence 3, R. I.
National Acme Co., 170 E 131st St., Cleveland 8, Ohio
National Aluminum & Brass Foundry, Inc., 1311 W Elm St., Independence, Mo.
National Aluminum Co., 1133 Alum Creek Dr., Columbus 9, Ohio
National Aluminum Co., Inc., 1912 Edgewood Ave., Racine, Wis.
National Aluminum Mfg. Co., 720 Park Ave., Peoria, Ill.
National Brass Works, Inc., 2140 E 25th St., Los Angeles 58, Calif.
National Casein Sales, 601 W 80th, Chicago 20, Ill.
National Copper & Smelting Co., 1862 E 123rd St., Cleveland 6, Ohio
National Cored Forgings Co., Inc., Connecticut Ave., Box 119, South Norwalk, Conn.
National Cylinder Gas Co., Tube Turns Div., E Broadway, Louisville 1, Ky.

National Distillers & Chemical Corp., U.S. Industrial Chemicals Co. Div., 99 Park Ave., New York 16, N. Y. (Ad p 121)

National Electric Products Corp., 2 Gateway Center, Pittsburgh 22, Pa.
National Felt Co., 76 Summer St., Boston 10, Mass.
National Gasket & Washer Mfg. Co., Inc., 124 E 25th St., New York 10, N. Y.
National Iron Co., 50th Ave. W & Famsey St., Duluth 7, Minn.
National Lead Co., 111 Broadway, New York 6, N. Y.
Doehler-Jarvis Div., Toledo 1, Ohio
Metal Div., 111 Broadway, New York 6, N. Y.
Titanium Pigment Corp., 111 Broadway, New York, N. Y.
National Lead Construction Co., 265 Kings Hwy. W, Haddonfield, N. J.
National Malleable & Steel Castings Co., 10600 Quincy Ave., Cleveland 6, Ohio
National Mfg. Corp., 153 Filmore Ave., Tonawanda, N. Y.
National Metal Abrasive Co., 3560 Nortin Rd., Cleveland 11, Ohio
National Metal Products Co., Porcelain Metal Products Div., Roslyn Rd., Carnegie, Pa.
National Molded Products, Inc., 40 St. Marys St., St. Marys, Pa.
National Moldite Co., 1410 Chestnut Ave., Hillside 5, N. J.
National Paint & Manganese Co., Lynchburg, Va.
National Paint Products, Inc., 500 Chancellor Ave., Irvington 11, N. J.
National Polymer Products, Inc., 125 N 4th St., Reading, Pa.
National Radiator Co., 342 Madison Ave., New York 17, N. Y.
National-Standard Co., 8th & Howard St., Niles, Mich.
Reynolds Wire Div., 809 E 2nd St., Dixon, Ill.
Worcester Wire Works Div., 70 James St., Worcester 3, Mass.
National Starch Products, Inc., 270 Madison Ave., New York 16, N. Y.
National Steel & Shipbuilding Corp., Harbor Dr. & 28th St., San Diego 12, Calif.
National Supply Co., 2 Gateway Center, Pittsburgh 30, Pa.
National Tank Co., Wells & Sandspring Rd., Tulsa, Okla.
National-U.S. Radiator Corp., Plastic Metals Div., 4457 Bridge St., Johnstown, Pa.
National Vulcanized Fibre Co., Box 311, Wilmington 99, Del.
Naugatuck Automatics, Inc., New Haven Rd., Naugatuck, Conn.
Neilson Chemical Corp., 6559 Benson St., Detroit, Mich.
Nesbitt Industries, Inc., 1823 Milwaukee Ave., Chicago 47, Ill.
Nesor Alloy Products Co., 282 Halsey St., Newark 2, N. J.
New Britain Machine Co., South St., New Britain, Conn.
New England Brass Co., 16 Parks Ave., Taunton, Mass.
New England Electrical Works, Inc., 365 Main St., Lisbon, N. H.
New England Laminates Co., Inc., 481 Canal St., Stamford, Conn.
New England Smelting Works, Inc., 502 Union St., West Springfield, Mass.
New England Tape Co., Inc., 40 Tower St., Hudson, Mass.
New Haven Copper Co., Main St., Seymour, Conn.
New Haven Screw Machine Products, Inc., 561 Boston Post Rd., Milford, Conn.
New Jersey Aluminum Extrusion Co., Inc., P. O. Box 73, North Brunswick, N. J.
New Jersey Metals Co., 712 Rockefeller St., Elizabeth 2, N. J.
New Jersey Zinc Co., 160 Front St., New York 38, N. Y.
New Mexico Copper Corp., P. O. Box 56, Carrizozo, N. Mex.

New Products Corp., 448 North Shore Ave., Benton Harbor, Mich. (Ad p 319)

New York Iron Roofing & Corrugating Co., Inc., 94 1st St., Jersey City 2, N. J.
Newark Wire Cloth Co., 357 Verona Ave., Newark 4, N. J.
Newman Bros., Inc., 670 W 4th St., Cincinnati 3, Ohio
Newman Crosby Steel Co., Deane St., Pawtucket, R. I.
Newport Steel Corp., 9th & Thomas Sts., Newport, Ky.
Newton-New Haven Co., 680 3rd Ave., West Haven, Conn.
Newtown Mfg. Co., Newtown, Conn.
Ney, J. M. Co., P. O. Box 990, Hartford 1, Conn.
Nichols, L. O. & Son Mfg. Co., 1625 Locust St., Kansas City 8, Mo.
Nichols Wire & Aluminum Co., 1725 Rockingham Rd., Davenport, Iowa
Nicoud Mfg. Co., 3220 Grand Ave., Chicago 51, Ill.
Nigg Engineering Corp., 545 N 2nd Ave., Corina, Calif.
Nikoh Tube Co., 5000 S Whipple St., Chicago 32, Ill.
Nikolas, G. J. & Co., Inc., 2890 Washington Blvd., Bellwood, Ill.
Niles Corp., 2827 Dixie Way N, South Bend, Ind.
Nilsen Mfg. Co., Electronicast Div., 21 North Church St., Addison, Ill.
Nixon Nitration Works, Nixon, N. J.
Noera Mfg. Co., 236 Grand St., Waterbury 20, Conn.
Nolte Screw Machine Products Co., 1534 Freeman Ave., Cincinnati 14, Ohio
Nopco Chemical Co., Inc., Harrison, N. J.
Norcross, C. S. & Sons Co., Dean & Davis Sts., Bushnell, Ill.
Norgren-Stemac, Inc., 1277 S Cherokee St., Denver 23, Colo.
North American Philips Co., Inc., Elmet Div., Lewiston, Me.
North Wales Foundry Co., Inc., Wissahickon Ave., North Wales, Pa.
Northern Industrial Chemical Co., Inc., 7 Elkins St., South Boston 27, Mass.
Northern Malleable Iron Co., 867 Forest St., St. Paul 6, Minn.
Northern Plastics Corp., Market St., La-Crosse, Wis.
Northwest Automatic Products Corp., 1770 Linden Ave., Minneapolis 3, Minn.
Northwest Chemical Co., Inc., 9310 Roselawn Ave., Detroit 4, Mich.
Northwest Plastics Inc., 65 E Plato, St. Paul, Minn.
Northwest Plastics Industries, Inc., 2040 15th Ave. W, Seattle 99, Wash.
Northwestern Machine Corp., 3014 Hadley St., St. Louis 7, Mo.

Norton Co., 1 New Bond St., Worcester 6, Mass. (Ad p 265)

Norwich Leather Co., 685 N Main St., Norwich, Conn.
Nukem Products Corp., 111 Colgate Ave., Buffalo, N. Y.

Nu-Ply Corp., Bemidji, Minn.
Nutmeg Screw Machine Products Co., Wolcott Rd., Wolcott, Conn.

O

Oakes Bronze & Aluminum Co., Bronze Rd., Warren, Ohio
Oakland Foundry & Machine Co., 607-621 Woodward Ave., Rochester, Mich.
Oatey, L. H. Co., 10230 Berea Rd., Cleveland 2, Ohio
Oberdorfer Foundries, Inc., Thompson Rd., Syracuse 1, N. Y.
Octagon Process Inc., Bank & Jersey Sts., Staten Island, N. Y.
Ohio Adhesive Corp., P. O. Box 466, New Philadelphia, Ohio
Ohio Carbon Co., 12508 Berea Rd., Cleveland 11, Ohio
Ohio Crankshaft Co., 4621 E 71st St., Cleveland 1, Ohio
Ohio Forge & Machine Corp., 3010 Woodhill Rd., Cleveland 4, Ohio
Ohio Metal Products Co., 35 N Bates St., Dayton 2, Ohio
Ohio Nut & Washer Co., Box 66, Mingo Junction, Ohio
Ohio Precision Castings, Inc., 109 Webb St., Dayton 3, Ohio
Ohio Rubber Co., 301 Ben Hur Ave., Willoughby, Ohio
Ohio Screw Products, Inc., 818 West St., Elyria, Ohio
Ohio Steel Foundry Co., 1075 James St., Springfield, Ohio
Oil City Iron Works, S 12th St. & S. P. R. R., Corsicana, Tex.
Olderman Mfg. Corp., P. O. Box 917, Bridgeport, Conn.
Olds Alloys Co., 4481 Mason St., South Gate, Calif.
Olean Electro Plating Co., 890 N 5th St., Olean, N. Y.
Olin Mathieson Chemical Corp., 460 Park Ave., New York 22, N. Y. (Ad p 124)
Western Brass Mills Div., 125 Munson St., New Haven 4, Conn.
Olson Mfg. Co., 100 Prescott St., Worcester 5, Mass.
Olympic Steel Works, 151 Horton St., Seattle 4, Wash.
Omaha Steel Works, 609 S 48th St., Omaha 6, Neb.
Omco Products Corp., 907 Wheel St., Springfield, Ohio
Omni Products Corp., 460 4th Ave., New York 16, N. Y.
Orange Rollerbearing Co., Inc., 557 Main St., Orange, N. J.
Oregon Brass Works, 1127 SE 10th Ave., Portland 14, Ore.
Oregon Metallurgical Corp., Albany, Ore.
Ormond Mfg. Co., Inc., 3325 Hudson Ave., Union City, N. J.
O'Sullivan Rubber Corp., Valley Pike St., Winchester, Va.
Owen Mfg. Co., S State Street Rd., Litchfield, Ill.
Owen Pattern Foundry & Mfg. Co., Inc., 710 W 22nd St., Norfolk 10, Va.
Owens-Corning Fiberglas Corp., 598 Madison Ave., New York 22, N. Y.
Owens-Illinois Glass Co., Toledo, Ohio

P

Pabst Engineering Equipment Co., Inc., 676 Pennsylvania Ave., Elizabeth 3, N. J.
Pacific Brass Foundry of San Francisco, 251 2nd St., San Francisco, Calif.
Pacific Coast Foil Co., 500 Sansome St., San Francisco, Calif.
Pacific Foundry Co., Ltd., 3100 19th St., San Francisco 10, Calif.
Pacific Screw Products Co., 930 Linden Ave., South San Francisco, Calif.
Pacific Sintered Metals Co., 7728 El Manor Ave., Los Angeles, Calif.
Pacific States Steel Corp., Niles, Calif.
Pacific Tube Co., 5710 Smithway St., Los Angeles 22, Calif.
Page Belting Co., Concord, N. H.
Palmyra Foundry Co., Inc., Palmyra, N. J.
Pan-American Metal Products Co., Inc., 401 NW 71st St., Miami 38, Fla.
Paramount Die Casting Co., St. Joseph 23, Mich.
Paramount Paint & Lacquer Co., 3411 E 15th St., Los Angeles 23, Calif.
Park Drop Forge Co., 777 E 79th St., Cleveland 3, Ohio
Parker Appliance Co., Rubber Products Div., 17325 Euclid Ave., Cleveland 12, Ohio
Parker, Charles Co., Hanover St., Meriden, Conn.
Parker & Harper Mfg. Co., 119 Dewey St., Worcester 10, Mass.
Parker Metal Goods Co., 85 Prescott St., Worcester, Mass.
Parker Paint Mfg. Corp., Locust & Poplar Sts., Valparaiso, Ind.
Parker Rust Proof Co., 2177 E Milwaukee St., Detroit 11, Mich.
Parker, Stearns & Co., Inc., 300 Sheffield Ave., Brooklyn 7, N. Y.
Parker White Metal Co., 2153 McKinley Ave., Erie, Pa. (Ad p 357)
Parr Paint & Color Co., 18312 Syracuse Ave., Cleveland 10, Ohio
Patterson Foundry & Machine Co., 41 Helene St., East Liverpool, Ohio
Patterson-Sargent Co., 1325 E 38th St., Cleveland 14, Ohio
Pattin Mfg. Co., Box 527, Marietta, Ohio
Paulson, Thomas & Son, Inc., 450 Union St., Brooklyn 31, N. Y.
Pawling Rubber Corp., Pawling, N. Y.
Payson Corp., 420 Lexington Ave., New York 17, N. Y.
Peck Spring Co., 80 Whiting St., Plainville, Conn.
Peerless Alloy Co., 1445 Osage St., Denver 4, Colo.
Peerless Automatic Machine Co., 1970 W 77th St., Cleveland 2, Ohio
Peerless Industries, Inc., 8050 N Territorial Rd., Plymouth, Mich.
Peerless Molded Plastics, Inc., 401 Hamilton Ave., Toledo 2, Ohio
Peerless Products Industries, 812-14-16 N Pulaski Rd., Chicago 51, Ill.
Peerless Roll Leaf Co., Inc., 4511 New York Ave., Union City, N. J.
Pemco Wheel Co., 1872 Ravine Rd., Kalamazoo, Mich.
Penberthy Instrument Co., 4301 6th Ave. S, Seattle 8, Wash.
Penn Brass & Copper Co., 3837 W 20th St., Erie, Pa.
Penn Extrusion Corp., 3837 W 20th St., Erie, Pa.
Penn Fibre & Specialty Co., Inc., 2026 E Westmoreland St., Philadelphia 34, Pa.
Penn Precision Products, Inc., 501 Crescent Ave., Reading, Pa.
Penn Veneer Co., Inc., Sumner St. & Penn R. R. York, Pa.
Pennsalt Chemicals Corp., 3 Penn Center, Philadelphia 2, Pa.
Pennsylvania Engineering Corp., P. O. Box 311, New Castle 17, Pa.
Pennsylvania Malleable Iron Corp., 712 S Prince St., Lancaster, Pa.
Penrod, Floyd & Sons Tool & Engineering Corp., 1208 W 2nd St., Muncie, Ind.
Pequonnock Foundry, Inc., 335 5th St., Bridgeport, Conn.
Perfex Plastics, Inc., 2632 S Dearborn, Chicago 16, Ill.
Perkins, Henry Co., Bridgewater, Mass.
Permanent Filter Corp., 1800 W Washington Blvd., Los Angeles 7, Calif.
Permold Co., P. O. Box 70, Medina, Ohio
Perrin, Edward C. Co., 3rd & Grant Sts., Camden 2, N. J.
Perry Fay Co., 200 Perry Ct., Elyria, Ohio
Perry-Austin Mfg. Co., 240 Parkinson Ave., Staten Island 5, N. Y.
Peterson Products Corp., 1735 W Armitage Ave., Chicago 22, Ill.
Pettibone Mulliken Corp., 4700 W Division St., Chicago 51, Ill.
Pfaudler Co., West Ave. & Clark St., Rochester 3, N. Y.
Pfister Aluminum Corp., 475 Franklin Turnpike, Allendale, N. J.
Phelps Dodge Copper Products Corp., 300 Park Ave., New York 22, N. Y.
Phelps Dodge Refining Corp., 40 Wall St., New York, N. Y.
Philadelphia Asbestos Corp., 2010 N 10th St., Philadelphia 22, Pa.
Philadelphia Enameling Works, Inc., Plastics Div., 256 N 13th St., Philadelphia 7, Pa.
Philadelphia Steel & Wire Corp., Penn St. & Belfield Ave., Philadelphia 44, Pa.
Phillips, F. C. Inc., 471 Washington St., Stoughton, Mass.
Phillips Bros. Screw Products Co., 2909 S Logan St., Lansing 17, Mich.
Phillips Petroleum Co., Phillips Chemical Co., Bartlesville, Okla.
Philrus Products Co., 135 Newark St., Newark 4, N. J.
Phoenix Die Casting Co., 21-23 Illinois St., Buffalo 3, N. Y.
Phoenix Products Co., 4715 N 27th St., Milwaukee 9, Wis.
Picco, Inc., 335 S Raymond Ave., Pasadena 1, Calif.
Pierce, F. O. Co., 2-33 50th Ave., Long Island City 1, N. Y.
Pierce Governor of Ohio, Inc., S.T.D. Div., Asbestos Ave., Alliance, Ohio
Pierce & Stevens Chemical Corp., 710 Ohio St., Buffalo, N. Y.
Pilgrim Plywood Corp., Waterbury, Vt.
Pioneer Aluminum Inc., 5251 W Imperial Blvd., Los Angeles 45, Calif.
Piper Tool Co., Inc., 556 Jefferson Court, Detroit 7, Mich.
Pittsburgh Corning Corp., 1 Gateway Center, Pittsburgh 22, Pa.
Pittsburgh Crushed Steel Co., 4839 Harrison St., Pittsburgh 1, Pa.
Pittsburgh Die & Casting Co., 7503 Ardmore St., Pittsburgh 18, Pa.
Pittsburgh Forgings Co., Thorn St., Coraopolis, Pa.
Pittsburgh Forgings Co., 919 Amur St., Jackson, Mich.
Pittsburgh Foundry & Machine Co., 36th St., Pittsburgh 1, Pa.
Pittsburgh Plate Glass Co., 632 Fort Duquesne Blvd., Pittsburgh 22, Pa.
Fiber Glass Div., 1 Gateway Center, Pittsburgh 2, Pa.
Forbes Finishes Div., 3800 W 143rd St., Cleveland 11, Ohio
Pittsburgh Smelting & Refining Co., 100 W Elizabeth St., Pittsburgh 7, Pa.
Pittsburgh Steel Co., Thomas Strip Div., Grant Bldg., Pittsburgh 30, Pa. (Ad pp 74, 75)
Pittsburgh Steel Foundry Corp., P. O. Box 986, Pittsburgh 30, Pa.
Pittsburgh Tool Steel Wire Co., Monaca, Pa.
Plast-Ad Mfg. Co., 22 N Michigan St., South Bend, Ind.
Plastex Co., 3232 Cleveland Ave., Columbus 24, Ohio

Plastic Masters, Inc., U.S. 12 W, New Buffalo, Mich.
Plastic Mold & Tool Co., 7347 State Rd., Philadelphia 35, Pa.
Plastic Packaging Co., 2025 W Charleston St., Chicago 47, Ill.
Plastic Pipe & Tube Corp., 224 S Mipas St., Santa Barbara, Calif.
Plastic Process Co., Inc., 10400 Aviation Blvd., Los Angeles 45, Calif.
Plastic Products Co., 6475 Georgia St., Detroit 11, Mich.
Plastic & Rubber Products, 2100 Hyde Park Blvd., Los Angeles 47, Calif.
Plastics Engineering Co., 1607 Geele Ave., Sheboygan, Wis. (Ad p 196)
Plax Corp., Box 1019, Hartford, Conn.
Plumb Chemical Corp., 4837 James St., Philadelphia 37, Pa.
Plume & Atwood Mfg. Co., N Main St., Thomastown, Conn.
Plura Plastics, 17-21 Newark Way, Maplewood, N. J.
Plymouth Industrial Products, Inc., 502 Indiana Ave., Sheboygan, Wis.
Pohlman, R. L. Co., 6730 Olive Street Rd., St. Louis 5, Mo.
Pohlman Foundry Co., Inc., Buffalo, N. Y.
Polacoat, Inc., 9752 Conklin Rd., Cincinnati 42, Ohio
Polo Plastics Co., 1718 N 1st St., Milwaukee 12, Wis.
Polyform Plastics Corp., 24 University Pl., New York 3, N. Y.
Polymer Chemical Co., 5920 Carthage Ave., Cincinnati 12, Ohio
Polymer Corp., 2120 Fairmont Ave., Reading, Pa. (Ad p 195)
Polyphase Machine Co., 43-22 50th St., Woodside 77, L. I., N. Y.
Polyplastic Products, Inc., 24th Ave., Paterson, N. J.
Poor & Co., Canton Forge & Axle Works, 2025 Dueber Ave. SW, Canton 6, Ohio
Porcelain Enamel Finishers, 3221 W 35th St., Chicago 23, Ill.
Porcelain Metals Corp. of Louisville, 1400 S 13th St., Louisville 10, Ky.
Porcelain Products, Inc., N Patterson St., Carey, Ohio
Portable Electric Tools, Inc., Admiral Die Castings Div., 250 W 83rd St., Chicago 20, Ill.
Porter, H. K. Co., Inc., 50 Foley St., Somerville, Mass.
Connors Steel Div., Box 118, Huntington 6, W. Va.
Quaker Rubber Div., Tacony & Comly Sts., Philadelphia 24, Pa.
Riverside-Alloy Metal Div., 1 Pavilion Ave., Riverside, N. J.
Porter, William Co., 1007 Santa Fe Ave., Los Angeles 21, Calif.
Porter Paint Co., 14th & Cedar Sts., Louisville 1, Ky.
Portland Co., 58 Fore St., Portland, Me.
Portland Iron Works, 1335 NW Northrup St., Portland 9, Ore.
Posey Iron Works, Inc., 560 S Prince St., Lancaster, Pa.
Potts & Co., C. & G., 816 Washington Ave., Indianapolis, Ind.
Powder Metals Products Co., 500 St. Marys St., St. Marys, Pa.
Powdercraft Corp., 746 Hayne St., Spartanburg, S. C.
Powell Pressed Steel Co., Erie St., Hubbard, Ohio
Practi-Cole Products, Inc., 130 Chapel St., New Haven 13, Conn.
Pratt & Lambert, Inc., 75 Tonawanda St., Buffalo 7, N. Y.
Precision Castparts Co., 5001 SE Johnson Creek Blvd., Portland 6, Ore.
Precision Extrusions, Inc., 132 S Addison St., Bensenville, Ill.
Precision Fabricating & Mfg. Co., 30020 Lakeland Blvd., Wickliffe, Ohio
Precision Founders, Inc., 414 Heste St., San Leandro, Calif.
Precision Machine Co., 1110 E 22nd St., Indianapolis 2, Ind.
Precision Metal Products Co., 1946 Commerce St., Ellwood City, Pa.
Precision Metal Spinning Co., 9861 Dixie Hwy., Clarkston, Mich.
Precision Metalsmiths, Inc., 1081 E 200th St., Cleveland 17, Ohio
Precision Piece Parts, Inc., 712 S Logan St., Mishawaka, Ind.
Precision Screw Products Co., Inc., 4764 Valley Blvd., Los Angeles 32, Calif.
Precision Tube Co., Inc., Church Rd. & Wissahicken Ave., North Wales, Pa.
Premier Metal Works, Inc., 1616 S Clinton St., Chicago 16, Ill.
Prescott Co., 1610 15th St., Menominee, Mich.
Presmet Corp., 112 Harding St., Worcester 4, Mass.
Pressed Steel Tank Co., 1493 S 66th St., Milwaukee 14, Wis.
Presstite-Keystone Engineering Products Co., 3738 Chouteau Ave., St. Louis, Mo.
Presswork, Inc., Lead Alloy Products Div., 9100 Roselawn St., Detroit 4, Mich.
Presto Plastic Products Co., Inc., 11 E 26th St., New York 10, N. Y.
Prima Pipe Co., Southwest Div., 1108 Pulliam, San Angelo, Tex.
Prince Rubber Co., Inc., 1675 Niagara St., Buffalo 7, N. Y.
Prisma Products Corp., 2801 Frenchmen St., New Orleans 10, La.
Progressive Service Co., 2745 Locust St., St. Louis 3, Mo.
Protective Treatments Inc., 420 Dellrose Ave., Dayton, Ohio
Puget Sound Plywood, Inc., 230 E F St., Tacoma 2, Wash.
Pure Carbon Co., Inc., 441 Hall Ave., St. Marks, Pa.
Puritan Co., Inc., Beach & Lyell Aves., Rochester, N. Y.
Purolator Products, Inc., 970 New Brunswick Ave., Rahway, N. J.
Pusey & Jones Corp., Front & Poplar Sts., Wilmington 9, Del.
Pyramid Mouldings, Inc., 5353 W Armstrong Ave., Chicago 30, Ill.
Pyramid Plastics, Inc., 554 W Polk St., Chicago 7, Ill. (Ad p 344)
Pyro Plastics Corp., Pyro Park, Union, N. J.
Pyron Corp., Box E, LaSalle Station, Niagara Falls, N. Y. (Ad p 359)
Pyrosil, Inc., 1889 Front St., Cuyahoga Falls, Ohio

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Quaker Alloy Casting Co., Myerstown, Pa.
Quaker City Felt Co., 1734 Ludlow St., Philadelphia 3, Pa.
Quaker State Metals Co., P. O. Box 1167, Lancaster, Pa.
Quality Castings Co., 1004 N Main St., Orrville, Ohio
Quest, J. F. Foundry Co., 900 4th St. S, Minneapolis 15, Minn.
Quigley Co., Inc., 415 Madison Ave., New York 17, N. Y.

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Racine Screw Co., 1501 Clark St., Racine, Wis.
Racine Steel Castings Co., 1442 Forest St., Racine, Wis.
Rainier Metal Products Co., 2412 W 71st St., Chicago 29, Ill.
Rand Rubber Co., 397 Sumner Ave., Brooklyn 16, N. Y.
Randolph Products Co., 18 12th St., Carlstadt, N. J.
Rankin Forge Co., 117 Fort Pitt Blvd., Pittsburgh 22, Pa.
Rasco-Veeder Co., 1600 S Dearborn St., Chicago 16, Ill.
Rathbone Corp., Park St., Palmer, Mass.
Rathbun Molding Corp., 290 Rochester St., Salamanca, N. Y.
Ravenswood Machine Corp., 3325 N Knox Ave., Chicago 41, Ill.
Raybestos-Manhattan, Inc., 61 Willett St., Passaic, N. J.
Asbestos Textiles Div., Manheim, Pa.
Plastics Products Div., 61 Willett St., Passaic, N. J.
Reade Mfg. Co., Inc., 135 Hoboken Ave., Jersey City 2, N. J.
Reading Tube Corp., Empire State Bldg., 350 5th Ave., New York 1, N. Y.
Red Devil Mfg. Co., 1412 N Ogden Ave., Chicago 10, Ill.
Redmer Sons Co., 9136 W Belmont, Franklin Park, Ill.
Reed Plastics Corp., 116 Gold St., Worcester 8, Mass.
Reed & Prince Mfg. Co., 1 Duncan Ave., Worcester 1, Mass.
Rees' Sons, Hans, 39 Frankfort St., New York 38, N. Y.
Reese Metal Products Corp., 537 Howard Ave., Lancaster, Pa.
Refinery Castings Co., P. O. Box 5085, Dallas 22, Tex.
Reflin Co., 5730 Kearney Villa Rd., San Diego 11, Calif.
Regal Plastic Co., 2800 E 14th St., Kansas City 27, Mo.
Regal Ware, Inc., Kewaskum, Wis.
Reichhold Chemicals, Inc., RCI Bldg., White Plains, N. Y.
Reily Tar & Chemical Corp., 1615 Merchant Bank Bldg., Indianapolis 4, Ind.
Reinhold Engineering & Plastics Co., 12827 E Imperial Hwy., Norwalk, Calif.
Reliable Screw Machine Products, 4433 W Rice St., Chicago 51, Ill.
Reliable Spring & Wire Forms Co., 3167 Fulton Rd., Cleveland 9, Ohio
Reliance Plastic & Chemical Corp., 110 Kearney St., Paterson 2, N. J.
Reliance Steel Casting Co., 2818 Smallman St., Pittsburgh 22, Pa .
Reliance Varnish Co., 1901 Sheridan Rd., North Chicago, Ill.
Rem-Cru Titanium, Inc., Midland, Pa. (Ad p 136)
Remler Co., Ltd., 2101 Bryant St., San Francisco 10, Calif.
Ren Plastics, Inc., 5422 S Cedar Rd., Lansing 17, Mich.
Replac Corp., 2130 St. Clair Ave., Cleveland 17, Ohio
Republic Foil & Metal Mills, Inc., 55 Triangle St., Danbury, Conn.
Republic Lead Equipment Co., 7930 Jones Rd., Cleveland 5, Ohio
Republic Metals Co., Inc., 273 Green St., Brooklyn 22, N. Y.
Republic Steel Corp., Republic Bldg., Cleveland 1, Ohio
Steel & Tubes Div., 224 E 131st St., Cleveland 8, Ohio
Resin Industries, Olive St., Santa Barbara, Calif.
Resinold Engineering Corp., 3445 Howard St., Skokie, Ill.
Resistoflex Corp., Woodland Rd., Roseland, N. J.
Resolite Corp., P. O. Box 366, Zelienople, Pa.
Revere Copper & Brass Inc., 230 Park Ave., New York 17, N. Y.
Rex Corp., Hayward Rd., West Acton, Mass.

Addresses of Suppliers

Rex Metal Parts Co., 1295 W 78th St., Cleveland 2, Ohio
Rex Products Co., 1918 E 55th St., Cleveland 3, Ohio
Reynolds Chemical Products, Inc., 1200 N Main St., Ann Arbor, Mich. (Ad p 268)
Reynolds Mfg. Co., Springfield, Mass.
Reynolds Metals Co., 2500 S 3rd St., Louisville, Ky.
Industrial Parts Div., 2000 S 9th St., Louisville 1, Ky.
Plastics Div., Box 128, Grottoes, Va.
Rezolin, Inc., 1651 18th St., Santa Monica, Calif.
Rheem Mfg. Co., 7600 S Kedzie Ave., Chicago 29, Ill.
Rhoads, J. E. & Sons, 2100 W 11th St., Wilmington 99, Del.
Rhode Island Tool Co., 148 W River St., Providence 1, R. I. (Ad p 350)
Richardson Co., 2882 Lake St., Melrose Park, Ill. (Ad p 190)
Richmond Mfg. Co., 312 N York St., Houston 4, Tex.
Riegel Paper Corp., 260 Madison Ave., New York 16, N. Y.
Rigidized Metals Corp., 658 Ohio St., Buffalo 3, N. Y.
Rinshed Mason Co., Milford at Epworth, Detroit, Mich.
River Smelting & Refining Co., 4189 Rd., Cleveland, Ohio
Riverside Foundry Co., N Front St., Wrightsville, Pa.
Riverside Foundry & Galvanizing Co., 508 Harrison St., Kalamazoo, Mich.
Riverside Smelting & Refining Co., 4195 Bradley Rd., Cleveland 1, Ohio
Roanoke Iron Works, Inc., 605 3rd St. SE, Roanoke 10, Va.
Robertson, H. H. Co., 2400 Farmer Bank Bldg., Pittsburgh, Pa.
Robertson Steel & Iron Co., 72 Elm St., Cincinnati 2, Ohio
Robot Devices, Inc., Main St., Buchanan, Va.
Rochester Novelty Works, Inc., 485 Hague St., Rochester 6, N. Y.
Rockford Bolt & Steel Co., 126 Mill St., Rockford, Ill.
Rockwell Mfg. Co., LFM Mfg. Co., Inc., Atchison, Kan.
Rockwell Spring & Axle Co., Bossert Div., 1002 Oswego St., Utica 1, N. Y. (Ad p 341)
Roddis Plywood Corp., Marshfield, Wis.
Rodney Hunt Machine Co., 46 Mill St., Orange, Mass.
Roebling's Sons, John A. Corp. 640 S. Broad St., Trenton 2, N. J.
Rogers Corp., Rogers, Conn. (Ad pp 205, 206, 207, 208)
Rogers, Dayton Mfg. Co., 2824 13th Ave., Minneapolis 7, Minn.
Rogers, V. G. Plastic Molding, 4320 Fox St., Denver 16, Colo.
Rohm & Haas Co., Washington Sq., Philadelphia 5, Pa.
Roll Formed Products Co., 3752 Oakwood Ave., Youngstown, Ohio (Ad p 329)
Roll Furnace Products Co., 3752 Oakwood Ave., Youngstown, Ohio
Rolle Mfg. Co., 3rd & Cannon St., Lansdale, Pa. (Ad p 346)
Rolock, Inc., 1282 Kings Hwy., Fairfield, Conn.
Rome Strip Steel Co., Inc., 530 Henry St., Rome, N. Y.
Rome Turney Radiator Co., Rome, N. Y.
Rosco Laboratories, 29 Moore St., Brooklyn 6, N. Y.
Rose Iron Works, Inc., 1539 E 43rd St., Cleveland 3, Ohio
Rosedale Foundry & Machine Co., 1731 Preble Ave., Pittsburgh 33, Pa.
Ross-Meehan Foundries, 1601 Carter St., Chattanooga 1, Tenn.
Rostone Corp., Lafayette, Ind.
Roth Rubber Co., 1854 S 54th St., Chicago 50, Ill.
Roth Steel Products Co., 1335 E 171st St., Cleveland 10, Ohio
Rotometals, 980 Harrison St., San Francisco 7, Calif.
Rowland Products, Inc., Fairview Lane, Kensington, Conn.
Rubber & Asbestos Corp., 225 Belleville Ave., Bloomfield, N. J.
Rubber Corp. of America, New South Rd., Hicksville, N. Y.
Ruberoid Co., Vermont Asbestos Mines Div., 500 5th Ave., New York 36, N. Y.
Rupert Diecasting Co., 1658 Cleveland Ave., Kansas City 27, Mo.
Russel, Burdsall & Ward Bolt & Nut Co., Port Chester, N. Y.
Russel Reinforced Plastics Corp., 521 W Hoffman Ave., Lindenhurst, N. Y.
Rust-Oleum Corp., 2425 Oakton St., Evanstown, Ill.
Rutenber Electric Co., 201 E Charles St., Marion, Ind.
Ryerson, Joseph T. & Son Inc., 2558 W 16th St., Chicago 8, Ill.

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St. Joseph Lead Co., 250 Park Ave., New York 17, N. Y.
St. Louis Diecasting Corp., 4528 Oleatha Ave., St. Louis 16, Mo.
St. Louis Malleable Casting Co., St. Louis 15, Mo.
St. Louis Steel Casting Inc., 100 Mott St., St. Louis 11, Mo.
St. Marys Carbon Co., State St., St. Marys, Pa.
St. Marys Foundry Co., 405-409 E South St., St. Marys, Ohio
St. Pierre Chain Corp., 50 Frank St., Worcester 4, Mass.
St. Regis Paper Co., Panelyte Div., 230 Park Ave., New York 17, N. Y.
Salem Tool Co., 767 S Ellsworth Ave., Salem, Ohio
Sall Bros. Co., 2300 Kishwaukee St., Rockford, Ill.
Sall, George Metals Co., 2302 E Butler St., Philadelphia 37, Pa.
Sandusky Foundry & Machine Co., W Market St., Sandusky, Ohio (Ad p 322)
Sandvik Steel, Inc., 1702 Nevins Rd., Fair Lawn, N. J. (Ad p 67)
Sandy Hill Iron & Brass Works, 27 Allen St., Hudson Falls, N. Y.
Sargent & Greenleaf, Inc., 24 Seneca Ave., Rochester 21, N. Y.
Sauereisen Cements Co., 1045 N Canal St., Pittsburgh 15, Pa.
Saxonburg Ceramics, Saxonburg, Pa.
Scaife Co., 126 Ann St., Oakmont, Pa.
Schachner Leather & Belting Co., 1123 S Mint St., Charlotte 1, N. C.
Schenectady Varnish Co., Inc., Schenectady Resins Div., Congress St. & 9th Ave., Schenectady 3, N. Y.
Schilling Bronze Co., 202-216 E North St., Rome, N. Y.
Schmeller Aluminum Foundry Co., 3300 E 87th St., Cleveland 27, Ohio
Schneider Bowman Co., Inc., 1612 Van Dyke St., Philadelphia 24, Pa.
Schumann, I. & Co., 4391 Bradley Rd., P. O. Box 2219, Cleveland 9, Ohio
Schwab Plastics Corp., 730 S Dix St., Detroit 17, Mich.
Schwartz Chemical Co., Inc., 326 W 70th St., New York 23, N. Y.
Schwarzkopf Development Corp., 595 Madison Ave., New York 22, N. Y.
Scott Chemical Corp., 241 W Jefferson, Los Angeles 7, Calif.
Scottdale Ozone Co., Crescent St., Scottdale, Pa.
Scovill Mfg. Co., Waterbury 20, Conn. (Ad pp 137, 138)
Scullin Steel Co., 6700 Manchester Ave., St. Louis 10, Mo.
Seaboard Refractories Co., Seamul Products, Perth Amboy, N. J.
Sealview Plastics, Inc., 1010 Ford St., West Conshohocken, Pa.
Sealube Co., Wakefield, Mass.
Seaman Products, 120 W Providencia Ave., Burbank, Calif.
Seamless Rubber Co., 464 Congress Ave., New Haven 3, Conn.
Seaporcel Metals, Inc., 28020 Borden Ave., Long Island City 1, N. Y.
Searjeant Metal Products, Inc., Mendon-Pittsford Rd., Mendon, N. J.
Seasholts, J. M. & Sons, Inc., Front & Spruce Sts., Reading, Pa.
Seattle Boiler Works, Inc., 5237 E Marginal Way, Seattle, Wash.
Seattle Tent & Awning Co., 310 Westlake N, Seattle 9, Wash.
Seiberling Rubber Co., Plastics Div., Newcomerstown, Ohio
Selma Foundry & Machine Co., P. O. Box 662, Selma, Ala.
Sel-Rex Corp., 75 River Rd., Nutley 10, N. J.
Seltzer, George H. & Co., Ridley & B & O R. R., P. O. Box 66, Folsom, Pa.
Semon Bache & Co., 636 Greenwich St., New York 14, N. Y.
Seneca Wire & Mfg. Co., Fostoria, Ohio
Serrick Corp., Defiance, Ohio
Acme Machine Products Div., 1300 Batavia, Muncie, Ind.
Defiance Screw Machine Products Div., 731-33 Perry, Defiance, Ohio
Service Steel Co., 1435 Franklin St., Detroit 7, Mich.
Servwell Products Co., 6541 Euclid Ave., Cleveland 3, Ohio
Sewell Mfg. Co., 1019 E 10 Mile Rd., Hazel Park, Mich.
Seymour Mfg. Co., 21 Franklin St., Seymour, Conn. (Ad pp 122, 123)
Shamban, W. S. & Co., Meyer Rd., Box 176, Fort Wayne, Ind.
Shank Metal Products Co., 347 Madison Ave., New York 17, N. Y.
Sharon Steel Corp., Sharon, Pa.
Sharpsville Steel Fabricators, Inc., 6th & Main Sts., Sharpsville, Pa.
Shaw Insulator Co., 160 Coit St., Irvington 11, N. J.
Shawinigan Resins Corp., Springfield 2, Mass.
Shaw-Kendall Engineering Co., 120 N Superior St., Toledo 3, Ohio
Sheet Metal Mfg. Co., 6400 Southern Blvd., Youngstown 20, Ohio
Sheffield Bronze Paint Corp., 17814 Waterloo Rd., Cleveland 19, Ohio
Sheffield Foundry Co,. 2070 N Clybourn St., Chicago 14, Ill.
Shelby Instrument Co., 1701 Magnolia Ave., Long Beach, Calif.
Shelby Mfg. Co., E Russel Rd., Sidney, Ohio
Shell Chemical Corp., 50 W 50th St., New York, N. Y.
Sheller Mfg. Corp., Dryden Rubber Div., 1014 S Kildare Ave., Chicago 24, Ill.
Shenango Furnace Co., Centrifugally Cast Products Div., W 3rd St., Dover, Ohio
Sherman & Reilly, Inc., 1st & Broad Sts., Chattanooga, Tenn.

In contacting suppliers, please mention the Materials Selector

Sherwin Williams Co., 101 Prospect Ave. NW, Cleveland 1, Ohio
Pigment, Color & Chemical Div., 260 Madison Ave., New York 16, N. Y.
Shieldalloy Corp., West Blvd., New Field, N. J.
Shingle Leather Co., 1300 Walnut St., Camden 3, N. J.
Shoe Form Co., Aureline Ave., Auburn, N. Y.
Shriver, T. & Co., Inc., 850 Hamilton St., Harrison, N. J.
Shull Bros. Glass Co., 509 N 6th St., Millville, N. J.
Sibley Machine & Foundry Corp., 206 E Tutt St., South Bend 23, Ind.
Siems Bros., Inc., Trussbilt Div., 2575 Como Ave. W, St. Paul 8, Minn.
Sierra Electric Corp., 15100 S Figueroa St., Gardena, Calif.
Sillcocks Miller Co., 10 W Parker Ave., Maplewood, N. J.
Simon Products Co., 3211 W Grand St., Chicago 51, Ill.
Simonds Saw & Steel Co., 470 Main St., Fitchburg, Mass.
Simonsen Metal Products Co., 4444 W Chicago St., Chicago 51, Ill.
Sinclair Co., 60 Appleton St., Holyoke, Mass.
Sinko Mfg. & Tool Co., 7310 W Wilson Ave., Chicago 31, Ill.
Sintercast Corp. of America, 134 Woodworth Ave., Yonkers 2, N. Y.
Sintered Metals, Inc., 3400 Washington St., Boston 30, Mass.
Sioux City Foundry & Boiler Co., E 8th & Division Sts., Sioux City 2, Iowa
Sipi Metals Corp., 1720 N Elston Ave., Chicago 22, Ill.
Sivyer Steel Casting Co., 43rd & Mitchell Ave., Milwaukee 14, Wis.
Skookum Co., Inc., 8504 N Crawford St., Portland 3, Ore.
Skyline Industries, Titusville 1, Pa.
Small Tube Products, Inc., Main St., Waterbury, Conn.
Smith, A. O. Corp., 3533 N 27th St., Milwaukee 1, Wis.
Smith & Winchester Mfg. Co., South Windham, Conn.
Smith-Moon Steel Co., 9th & Millington, Winnfield, Kan.
Smith-Victor Corp., Griffith, Ind.
Smoot-Holman Co., P. O. Box 4097, Inglewood, Calif.
Snyder Mfg. Co., Inc., 1458 5th St. NW, New Philadelphia, Ohio
Snyder, M. L. & Son, Inc., 1856 E Boston Ave., Philadelphia 25, Pa.

Somers Brass Co., Inc., 94 Baldwin Ave., Westbury, Conn. (Ad p 130)

Somerset Foundry & Machine Co., 809-831 S Edgewood Ave., Somerset, Pa.
Sonith Industries, Inc., Indianapolis, Ind.
Sonken-Galamba Corp., 2nd & Riverview, Kansas City 18, Mo.
South River Metal Products Co., Inc., 377 Turnpike, South River, N. J.
Southern Belting Co., P. O. Box 4296, Atlanta 2, Ga.
Southern Car & Mfg. Co., Inc., 1831 29th Ave. N, Birmingham, Ala.
Southern Extrusions Co., N Washington St., Magnolia, Ark.
Southern Galvanizing Co., 1620 Bush St., Baltimore 30, Md.
Southern Plastics Co., 408 Pendleton St., Columbia, S. C.
Southwestern Plastic Pipe Co., P. O. Box 117, Mineral Wells, Tex.
Southwestern Porcelain Steel Corp., P. O. Box 607, Sand Springs, Okla.

Sparta Mfg. Co., Box 66, Dover, Ohio (Ad p 328)

Spaulding Fibre Co., Inc., 310 Wheeler St., Tonawanda, N. Y. (Ad p 212)

Special Leathers Co., 1920 E Venango St., Philadelphia 34, Pa.
Special Screw Products Co., 5445 Dunham Rd., Bedford, Ohio
Specialty Resins Co., Polyester Div., 2801 Lynwood Rd., Lynwood, Calif.
Speer Carbon Co., St. Marys, Pa.
Spencer Chemical Co., Dwight Bldg., Kansas City 5, Mo.
Spencer's Sons, I. S. Inc., 20 Fair St., Guilford, Conn.
Spincraft, Inc., 4122 W State St., Milwaukee 8, Wis.
Spiral-Glas Pipe Co., 47 Bayard St., New Brunswick, N. J.

Spraylat Corp., 1 Park Ave., New York 16, N. Y. (Ad p 279)

Spring City Foundry Co., Hall & Main Sts., Spring City, Pa.
Spring Packing Corp., 332 S Michigan Ave., Chicago 4, Ill.
Springer's Foundry Co., Inc., 201 S 1st St., Terre Haute, Ind.
Springfield Foundry Co., 295 Pasco Rd., Indian Orchard, Mass.
Spruce Pine Mica Co., Inc., P. O. Box 456, Spruce Pine, N. C.
Spuck Iron & Foundry Co., 3145 N 14th St., St. Louis, Mo.
Square D Co., Molded Insulation Div., 311 N Tippecanoe St., Peru, Ind.
Stackpole Carbon Co., Stackpole St., St. Marys, Pa.
Stacy Mfg. Co., Township Ave. & Big Four R. R., Cincinnati 16, Ohio
Stainless Foundry & Engineering, Inc., 5132 N 35th St., Milwaukee 9, Wis.
Stainless Metals, Inc., 19-42 42nd St., Long Island City, N. Y.
Stalwart Rubber Co., 160 Northfield Rd., Bedford, Ohio
Stamford Metal Specialty Co., Inc., 429 W Broadway, New York 12, N. Y.
Stamford Rolling Mills Co., Inc., Springdale, Conn.
Standard Asbestos Mfg. Co., 860 W Evergreen Ave., Chicago 22, Ill.
Standard Casting Corp., 4400 W Cermack Rd., Chicago 23, Ill.
Standard Forge & Axle Co., Inc., P. O. Box 309, Montgomery 1, Ala.
Standard Foundry Co., Worcester, Mass.
Standard Foundry Co., 1600 Kewanee St., Racine, Wis.
Standard Insulation Co., 74 Paterson Ave., East Rutherford, N. J.
Standard Magnesium Corp., 7500 E 41st St., Tulsa, Okla.
Standard Molding Corp., P. O. Box 188, Station A, Dayton 3, Ohio
Standard Nut & Bolt Co., Abbott St., Valley Falls, R. I.
Standard Products Co., 316 Fisher Bldg., Detroit, Mich.
Standard Screw Products Co., 506 S Palm Ave., Alhambra, Calif.

Standard Stamping & Perforating Co., 3129 W 49th Pl., Chicago 32, Ill. (Ad p 350)

Standard Steel Sections, Inc., 608 E 133rd St., New York, N. Y.
Standard Tube Co., 24400 Plymouth Rd., Detroit 29, Mich.
Standard Washer & Mat Inc., 155 Adams St., Manchester, Conn.
Stanley Chemical Co., Berlin St., East Berlin, Conn.
Stanwood Corp., 4819 Cortland, Chicago 39, Ill.
Star Porcelain Co., Muirhead Ave., Trenton 9, N. J.
Star Stamping Co., 1303 M-139, Benton Harbor, Mich.
Staver Co., Inc., 41-51 N Saxon Ave., Bay Shore, L. I., N. Y.
Stearns-Roger Mfg. Co., 660 Bannock St., Denver, Colo.
Steel Heddle Mfg. Co., 2100 W Allegheny Ave., Philadelphia 32, Pa.

Steel Improvement & Forge Co., 970 E 64th St., Cleveland, Ohio (Ad p 333)

Steel Industries, Inc., 907 Louise Ave., Crawfordsville, Ind.
Steel Protection & Chemical Co., Inc., Bridge St., Mooresville, Ind.
Steel Shot Producers, Inc., Etna St., P. O. Box 67, Butler, Pa.
Steel, R. & Sons, Inc., 42-21 9th St., Long Island City 1, N. Y.
Steelcote Mfg. Co., 3418 Gratiot, St. Louis 3, Mo.
Stenman, Bror F., West St., Auburn, Mass.
Sterling Aluminum Products, Inc., 2600 N 3rd St., St. Charles, Mo.
Sterling Brass Foundry, Inc., 1640 Sterling Ave., Elkhart, Ind.
Sterling Die Casting Co., 743 39th St., Brooklyn 32, N. Y.
Sterling Foundry Co., 8 Wallace St., Sterling, Ill.
Sterling Steel Casting Co., 2500 Monsanto Ave., Monsanto, Ill.
Sterrit-Thomas Foundry Co., 32nd & Smallman St., Pittsburgh 1, Pa.
Stevens, A. T. Co., 118 E 28th St., New York 16, N. Y.
Steward, D. M. Mfg. Co., E 36th St., Chattanooga, Tenn.
Stillman White Foundry Co., 51 Mill St., Providence, R. I.
Stimpson, Edwin B. Co., Inc., 70 Franklin Ave., Brooklyn 5, N. Y.
Stirrup Metal Products Corp., 215 Emmet St., Newark 5, N. J.
Stockwell Rubber Co., Inc., 1117 Shackamaxon St., Philadelphia 25, Pa.
Stone Paper Tube Co., Stonized Products Div., 900-902 Franklin St. NE, Washington 17, D. C.
Stover Steel Tank & Mfg. Co., 100 S Hancock St., Freeport, Ill.
Stranahan Foil Co., Inc., 100 Wesley St., South Hackensack, N. J.
Strick Plastics Co., Perkasie, Pa.
Strong Steel Foundry Co., 33 Norris St., Buffalo 7, N. Y.
Struthers Wells Corp., Process Equipment Div., Warren, Pa.
Stuart Foundry Co., 138 S Junction St., Detroit, Mich.
Stulz-Sickles Co., Port Ave. & Julia St., Elizabeth, N. J.
Subox, Inc., Fairmount Plant, Hackensack, N. J.
Sun Chemical Corp., 10th St. & 44th Ave., Long Island City 1, N. Y.
Sun Rubber Co., 366 Fairview Ave., Barberton, Ohio
Sun Tube Corp., 181 Long Ave., Hillside, N. J.
Sunlite Plastics, Inc., 1512 W Pierce St., Milwaukee, Wis.
Superb Light Alloys Inc., Box 270, Allan Blvd., Farmingdale, N. Y.
Superior Bearing Bronze Co., 139 Banker St., Brooklyn, N. Y.

Superior Carbon Products, Inc., 9115 George Ave., Cleveland 5, Ohio (Ad p 344)

Superior Die Casting Co., 1001 London Rd., Cleveland 10, Ohio
Superior Drawn Steel Co., 1585 Beaver Ave., Monaca, Pa.
Superior Industries, Inc., 3786 Oakwood Ave., Youngstown 9, Ohio
Superior Paint & Lacquer Works, 6231 Maywood Ave., Huntington Park, Calif.
Superior Plating Inc., 1064 10th Ave. SE, Minneapolis, Minn.
Superior Steatite & Ceramic Corp., 83-91

W Forest Ave., Englewood, N. J.
Superior Steel Corp., Carnegie, Pa.
Superior Steel & Malleable Castings Co., Benton Harbor, Mich.
Superior Tube Co., P. O. Box 191, Norristown, Pa. (Ad p 318)
Supreme Industrial Products Co., 367 N Karlov Ave., Chicago 24, Ill.
Surprenant Mfg. Co., 199 Washington St., Boston 8, Mass.
Swedish Crucible Steel Co., 8801 Conant Ave., Detroit 11, Mich.
Sweet's Steel Co., 6666 Sweet St., Williamsport, Pa.
Swepco Tube Corp., 1 Clifton Blvd., Clifton, N. J.
Swett, A. L. Iron Works, 172 Glenwood Ave., Medina, N. Y.
Sylvan Plastics Inc., 1617 Pennsylvania Ave., Philadelphia 3, Pa.
Sylvania-Corning Nuclear Corp., P. O. Box 59, Bayside, N. Y.
Sylvania Electric Products, Inc., 1740 Broadway, New York 19, N.Y.
Parts Div., Warren, Pa.
Tungsten & Commercial Div., Towanda, Pa.
Symington-Gould Corp., Depew, N. Y.
Synco Resins, Inc., Henry St., Bethel, Conn.
Synthane Corp., River Rd., Oaks, Pa. (Ad p 200)

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Taylor & Boggis Foundry, 1290 E 53rd St., Cleveland, Ohio
Taylor & Co., Inc., 680 Morgan Ave., Brooklyn 22, N. Y.
Taylor Fibre Co., Norristown, Pa.
Teal Co., 71 Wheeler St., New Haven, Conn.
Technical Specialties Co., 415 Concord Ave., New York 55, N. Y.
Tect, Inc., 59 Cortland Ave., Dumont, N. J.
Telner, Roland Co., Inc., 134 Tremont St., Everett 49, Mass. (Ad p 352)
Temco, Inc., 4101 Charlotte Ave., Nashville 9, Tenn.
Tempil Corp., 132 W 22nd St., New York 11, N. Y.
Tennessee Stove Works, 14th & Belt R. R., Chattanooga 1, Tenn.
Terre Haute Bronze & Brass Foundry, 1114 Sycamore St., Terre Haute, Ind.
Terre Haute Malleable & Mfg. Corp., 2030 N 19th St., Terre Haute, Ind.
Texas Aluminum Co., 1218 Mercantile Securities Bldg., Dallas, Tex.
Texas Foundries, Inc., P. O. Box 180, Lufkin, Tex.
Texas Glass Fiber Corp., 147 Island Grove Rd., Grandview, Tex.
Texas Plastic Development Corp., 2120 Post Oak Rd., Houston, Tex.
Texas Steel Co., 3901 Hemphill St., Ft. Worth 9, Tex.
Texas U.S. Chemical Co., Port Neches, Tex. (Ad pp 158, 159)
Texlite, Inc., 3305 Manor Way, Dallas 35, Tex.
Textile Shield Co., 1 Groton St., Lawrence, Mass.
Textron Inc., Campbell, Wyant & Cannon Foundry Div., Henry St., Muskegon, Mich.
Thalco, 765 S Harvard Blvd., Los Angeles, Calif.
Thermaflow Chemical Corp., Box 155, Tunkhannock, Pa.
Thermal Refractories Corp., 4301 Dell Ave., North Bergen, N. J.
Thermo Materials, Inc., 4040 Campbell Ave., Menlo Park, Calif.
Thinsheet Metals Co., 271-TR Railroad Hill St., Waterbury 20, Conn.
Thiokol Chemical Corp., 780 N Clinton Ave., Trenton 7, N. J.
Thombert, Inc., 316 E 7th St. N, Newton, Iowa
Thompson & Co., 1085 Allegheny Ave., Oakmont, Pa.
Thompson, H. I. Fiber Glass Co., 1733 Cordova St., Los Angeles 7, Calif. (Ad p 244)
Thompson Industries, Inc., Manhasset, N. Y.
Thompson, K. W. Tool Co., 20 Denton Ave., New Hyde Park, L. I., N. Y.
Thompson Pipe & Steel Co., 30th & Larimer Sts., Denver 1, Colo.
Thompson Products, Inc., Hydraulic Products Div., 2196 Clarkwood Rd., Cleveland 3, Ohio (Ad p 354)
Thompson Wire Co., 41 Mildred Ave., Boston 26, Mass.
Tickle, Arthur Engineering Works, Inc., 21 Delevan St., Brooklyn 31, N. Y.
Tiffin Enterprise, Inc., 458 2nd Ave., Tiffin, Ohio
Timber Products Co., P. O. Box 1032, Medford, Ore.
Timken Roller Bearing Co., 1835 Dueber Ave. SW, Canton 6, Ohio
Titan Metal Mfg. Co., Bellefonte, Pa.
Titanium Metals Corp. of America, 233 Broadway, New York 7, N. Y.
Titchner, E. H. & Co., 67 Clinton St., Binghamton, N. Y.
Toepfer & Sons, Inc., 2925 W Hope Ave., Milwaukee 16, Wis.
Toledo Industrial Rubber Co., 2242 Smead Ave., Toledo 6, Ohio
Toledo Stamping & Mfg. Co., 99 Fearing Blvd., Toledo 7, Ohio
Tool & Mfg. Co., Inc., P. O. Box 10344, Pittsburgh 34, Pa.
Topeka Foundry & Iron Works Co., Inc., 300-324 Jackson St., Topeka, Kan.
Torngren, C. W. Co., Inc., 236 Pearl St., Somerville 45, Mass.
Torrington Co., 59 Field St., Torrington, Conn.
Tousey Varnish Co., 520 W 25th St., Chicago 16, Ill.
Tower Grove Foundry, 4438 Hunt Ave., St. Louis 10, Mo.
Trane Co., 206 Cameron Ave., LaCrosse, Wis.
Transue-Williams, Ely St., Alliance, Ohio
Trent Tube Co., East Troy, Wis.
Trenton Brass Co., 621 Prospect St., Trenton, N. J.
Triangle Conduit & Cable Co., Inc., 6900 Jersey Ave., New Brunswick, N. J.
Triangle Stamping Co., 5101 Carnegie Ave., Cleveland 3, Ohio
Trim Alloys, Inc., 30-40 W 3rd St., Boston 27, Mass.
Tri-Point Mfg. & Developing Co., 171 I. U. Willets Rd., Alberton, L. I., N. Y. (Ad p 358)
Trojan Steel Co., 1414 McCookle Ave. SW, Charleston, W. Va.
Troy Blanket Mills, 200 Madison Ave., New York, N. Y.
Truche Leather Co., Peabody, Mass.
True Alloys, Inc., 284 S. Summit St., Detroit 9, Mich.
Tube Methods, Inc., Depot & Rambo Sts., Bridgeport, Pa.
Tube Reducing Corp., 520 Main Ave., Wallington, N. J.
Tube Turns Plastics, Inc., 2929 Magazine St., Louisville 11, Ky.
Tubular Rivet & Stud Co., Weston Ave., Wollaston 70, Mass.
Turco Products, Inc., 6135 S Central Ave., Los Angeles 1, Calif.
Turner & Seymour Mfg. Co., Lawton St., Torrington, Conn.
Tyler, W. S. Co., 3615 Superior Ave., Cleveland 14, Ohio

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U B S Chemical Corp., 491 Main St., Cambridge 42, Mass.
Udylite Corp., 1651 E Grand Blvd., Detroit 11, Mich.
Uniform Tubes, Inc., Level & School Rds., Collegeville 2, Pa.
Union Carbide Corp., 30 E 42nd St., New York 17, N. Y.
Bakelite Co., 420 Lexington Ave., New York 17, N. Y. (Ad p 201)
Electro Metallurgical Co., 30 E 42nd St., New York 17, N. Y.
Haynes Stellite Co., 725 S Lindsay St., Kokomo, Ind.
Linde Air Products Co., 30 E. 42nd St., New York 17, N. Y. (Ad p 427)
National Carbon Co. Div., 30 E 42nd St., New York 17, N. Y.
Silicones Div., 30 E 42nd St., New York 17, N. Y.
Union Chemical Corp., 410 Frelinghuysen Ave., Newark 5, N. J.
Union Forging Co., 500 North St., Endicott, N. Y.
Union Iron Works, P. O. Box 2135, Spokane, Wash.
Union Screw & Mfg. Co., Box 25, Imperial, Pa.
Union Spring & Mfg. Co., 2nd Ave. & 8th St., New Kensington, Pa.
Union Steel Corp., Ashwood Terrace, Union, N. J.
Union Tank Car Co., 228 N La Salle, Chicago, Ill.
Unitcast Corp., Box 8, Station E, Toledo 9, Ohio (Ad p 328)
United Carbon Products Co., 1310 N Madison St., Bay City, Mich.
United Cork Companies, 15 Central Ave., Kearney, N. J.
United Forge Co., 277 Dubois St., Detroit 7, Mich.
United International Research, Inc., 38-15 30th St., Long Island City 1, N. Y.
United Metal Products Corp., 8101 Lyndon St., Detroit 38, Mich.
United Plastic Industries, Inc., 1300 Water St., Vassar 3, Mich.
United Rubber & Chemical Co., P. O. Box 1913, Charleston 27, W. Va.
United Sintered Alloys, St. James, L. I., N. Y.
United Smelting & Aluminum Co., Inc., 187 Commerce St., New Haven 9, Conn.
U.S. Bronze Powder Works, Inc., Route 202, Flemington, N. J.
U.S. Ceramic Tile Co., Sparta Mfg. Co. Div., Box 66, Dover, Ohio (Ad p 328)
U.S. Challenge & Challenge Co., 1441 N Kingsburg St., Chicago 22, Ill.
U.S. Expansion Bolt Co., York, Pa.
U.S. Extrusions Corp., 120 Old Broadway, Garden City Park, L. I., N. Y.
U.S. Gasket & Shim Co., 2743 2nd St., Cuyahoga Falls, Ohio
U.S. Gypsum Corp., 300 W Adams St., Chicago 6, Ill.
U.S. Magnesium Co., Pleasant Valley, N. Y.
U.S. Metal Products Co., P. O. Box 1067, Erie, Pa.
U.S. Mica Co., Inc., 1525 Circle Ave., Forest Park, Ill.
U.S. Pipe & Foundry Co., 3300 1st Ave. N, Birmingham 3, Ala.
U.S. Plywood Corp., 55 W 44th St., New York 36, N. Y.
U.S. Polymeric Chemicals Inc., Canal & Ludlow Sts., Stamford, Conn.
U.S. Porcelain Enamel Co., 4731 E 52nd Dr., Los Angeles 22, Calif.
U.S. Reduction Co., Chicago Ave. & Melville

St., East Chicago, Ind.
U.S. Rubber Co., 1230 Ave. of the Americas, New York 20, N. Y.
Mechanical Goods Div., 4300 New Haven Ave., Ft. Wayne, Ind.
Naugatuck Chemical Div., Elm St., Naugatuck, Conn.
Royalite Div., 2638 N Pulaski Rd., Chicago 39, Ill. (Ad p 219)
U.S. Smelting, Refining & Mining Co., 57 William St., New York 5, N. Y.
U.S. Steel Corp., 525 William Penn Pl., Pittsburgh 30, Pa. (Ad pp 69, 70(71, 72)
American Steel & Wire Div., Cleveland, Ohio
Irvin Works, Dravosburg, Pa.
National Tube Div., 525 William Penn Pl., Pittsburgh 30, Pa.
U.S. Stoneware Co., 60 E 42nd St., New York 17, N. Y.
Alite Div., P. O. Box 119, Orrville, Ohio
U.S. Valve & Mfg. Co., 256 E Grand Ave., South San Francisco, Calif.
United Wire & Supply Corp., 1497 Elmwood Ave., Providence 7, R. I.
Unity Machine & Tool Corp., 2727 E Westmoreland St., Philadelphia 34, Pa.
Universal Castings Corp., 5821 W 66th St., Chicago 38, Ill.
University of Tennessee, Dept. of Chemistry, University Station, Knoxville, Tenn.
Urrite Plastics Fabricators, 4740-2 S Durfee Rd., Pico, Calif.
Utica General Jobbing Foundry, Inc., 1801 Foundry St., Utica 3, N. Y.
Utica Radiator Corp., Dwyer Ave., Utica, N. Y.
Utility Mfg. Co., 2443 Boston Rd., North Wilbraham, Mass.

V

Valley Iron Works, Inc., 81 E Water St., St. Paul 7, Minn.
Valley Steel Casting Co., 11th St., Bay City, Mich.
Valley-National Corp., Clark St., Milldale, Conn.
Vanadium Corp. of America, 420 Lexington Ave., New York 17, N. Y.
Vanadium-Alloys Steel Co., Latrobe, Pa.
Van Der Horst Corp., Olean, N. Y. (Ad p 271)
Vandersee Corp., 1414 Chestnut Ave., Hillside, N. J.
Vanguard Paints & Finishes, Inc., State St., Marietta, Ohio
Van Huffel Tube Corp., Larchmont Ave. NE, Warren, Ohio (Ad p 340)
Van Valkenburg, L. A. Co., Box 190, Holyoke, Mass.
Varcum Chemical Corp., Packard Rd., Niagara Falls, N. Y.
Veeder-Root Inc., 70 Sargent St., Hartford 2, Conn.
Veremere, E. A., Inc., 11623 S Broadway, Los Angeles 61, Calif.
Victor Steel Products Corp., 1175 Leggett Ave., New York 59, N. Y.
Victory Plastics Co., 81 Apsley St., Hudson, Mass.
Viking Copper Tube Co., 16716 St. Clair Ave., Cleveland, Ohio
Viplax Products Corp., 408 E Warren St., Beverly, N. J.
Visking Corp., 65th & Oak Park Ave., Chicago, Ill.
Fabrics Div., 1313 E 8th St., North Little Rock, Ark.
Plastics Div., P. O. Box 1410, Terre Haute, Ind.
Vitreous Steel Products Co., P. O. Box 3991, Cleveland 20, Ohio
Vogt Mfg. Corp., 100 Fernwood Ave., Rochester, N. Y.
Volco Brass & Copper Co., Childs Rd., Basking Ridge, N. J.
Volsonite Enterprises, Ltd., P. O. Box 628, Pasadena 19, Calif.
Vulcan Foundry Co., Oakland, Calif.
Vulcan Iron Works, 730 S Main St., Wilkesbarre, Pa.
Vulcan Mfg. Co., 120 Sycamore St., Cincinnati 2, Ohio
Vulcan Metal Products Inc., 2801 6th Ave. S, Birmingham, Ala.
Vulcan Rail & Construction Co., 59-30 54th St., Maspeth, N. Y.
Vulcan Varnish Co., 1112 Main St. W, Louisville 3, Ky.
Vulcanized Rubber & Plastics Co., 5 S Pennsylvania Ave., Morrisville, Pa.

W

W. F. Mfg. Co., 1509 Gardena Ave., Glendale 4, Calif.
WLS Stamping Co., 3292 E 80th St., Cleveland 4, Ohio
Wabash Metal Products Co., 1568 Morris St., Wabash, Ind.
Wabash Screen Door Co., 2222 Elm St. SE, Minneapolis 14, Minn.
Wagner, E. R. Mfg. Co., 4611 N 32nd St., Milwaukee 9, Wis.
Wagner Plastic Corp., 6500 Hudson Blvd., West New York, N. J.
Wagner Specialty Co., 647 Dodge St., Burlington, Wis.
Wakefield Bearing Corp., 35 Foundry St., Wakefield, Mass.
Walker Forge, Inc., 2000 17th St., Racine, Wis.
Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.
Wall Mar Corp., 2800 Bernice Rd., Lansing, Ill.
Wall, P. Mfg. Co., Erie St., Grove City, Pa.
Wallingford Steel Co., 80 Valley St., Wallingford, Conn.
Walsen Consolidated Mercantile Co., 2 Broadway, New York 4, N. Y.
Walsh Refractories Corp., 101 Ferry St., St. Louis 7, Mo.
Waltham Foundry Co., 71 Felton St., Waltham 54, Mass.
Ward, H. H., 4th & Engle Sts., Chester, Pa.
Warren Belting Co., 33 Arctic St., Worcester 8, Mass.
Warren Bros. Roads Co., 32 Potter St., Cambridge 42, Mass.
Washburn Wire Co., Phillipsdale Div., Bourne Ave., Phillipsdale, R. I.
Washington Iron Works, 1500 6th Ave. S, Seattle 4, Wash.
Washington Steel Corp., 1001 Berger Bldg., Washington, Pa.
Waterbury Buckle Co., 952 S Main St., Waterbury 20, Conn.
Waterbury Companies, Inc., 835 S Main St., Waterbury 20, Conn. (Ad p 326)
Waterbury Rolling Mills, Inc., E Aurora St., Waterbury 20, Conn. (Ad p 116)
Waterman Industries, Inc., 515 S G St., Exeter, Calif.
Watertown Mfg. Co., Echo Lake Rd., Watertown, Conn.
Watson Standard Co., Industrial Safety Products Div., 225 Galveston Ave., Philadelphia, Pa.
Waukesha Foundry Co., Lincoln Ave., Waukesha, Wis.
Wayne Agricultural Works, Inc., Goldsboro, N. C.
Wayne Foundry & Stamping Co., 3100 Hubbard St., Detroit 10, Mich.
Weber-Knapp Co., 441 Chandler St., Jamestown, N. Y.
Weckesser Co., 5713 Northwest Hwy., Chicago 30, Ill.
Wedler Bros., Inc., 1535 E 38th St., Cleveland 14, N. Y.
Weirton Steel Co., Weirton, W. Va. (Ad p 68)
Weiskittel, Harry C. Co., Inc., 4901 Pulaski Hwy., Baltimore 24, Md.
Welding Apparatus Co., 2750 W Van Buren St., Chicago 12, Ill.
Wellman Bronze & Aluminum Co., 12800 Shaker Blvd., Cleveland 20, Ohio
Wellman, S. K. Co., 200 Egbert Rd., Bedford, Ohio
Wellman Engineering Co., 7004 Central Ave., Cleveland 4, Ohio
Wells Aluminum Corp., North Liberty, Ind.
Wells, A. H. & Co., Inc., 100 E Aurora St., Waterbury, Conn.
Wells Specialty Co., Inc., Wells Aluminum Products Div., 151 Wells St., North Liberty, Ind.
Werner, R. D. Co., Inc., 295 5th Ave., New York 16, N. Y. (Ad p 358)
Werner Foundry & Machine Co., 8th St. & Reading R. R., Lansdale, Pa.
Wesbar Stamping Corp., West Bend, Wis.
Wesco Spring Co., 2266 S Archer St., Chicago 16, Ill.
West Haven Foundry Co., 27 Kimberly Ave., West Haven 16, Conn.
West Irving Die Casting Co., 24 S Evergreen St., Bensenville, Ill.
West Lake Plastics Co., 145 W Lenni Rd., Lenni Mills, Pa.
West Point Mfg. Co., Wellington Sears Co., 600 Worth St., New York, N. Y.
West Steel Casting Co., Westalloy Div., 1679 Collamer Rd., Cleveland 10, Ohio
West Virginia Malleable Iron Co., Point Pleasant, W. Va.
Western Automatic Machine Screw Co., 377 Woodland Ave., Elyria, Ohio
Western Coating Co., P. O. Box 598, Royal Oak 3, Mich.
Western Felt Co., 4029-4135 Ogden Ave., Chicago 23, Ill.
Western Foundry & Machine Works, Inc., 201 Jefferson St., Topeka, Kan.
Western Gold & Platinum Co., 525 Harbor Blvd., Belmont, Calif.
Western Iron & Foundry Co., Inc., 702 E 2nd St., Wichita 2, Kan.
Western Metal Abrasive Co., Chicago Heights, Ill.
Western Plastics Corp., 1515 W 2nd St., Hastings, Neb.
Western Tool & Die Works, 421 NW 3rd Ave., Portland 9, Ore.
Westinghouse Electric Corp., 101 Liberty Ave., Gateway Center, Pittsburgh, Pa.
Benolite Plant, Manor, Pa. (Ad p 269)
Lamp Div., Watsessing Center, Bloomfield, N. J.
Materials Mfg. Dept., Blairsville, Pa. (Ad p 348)
Micarta Div., Trafford, Pa.
Westlectric Castings, Inc., 2040 S Camfield Ave., Los Angeles 22, Calif.
Westmoreland Malleable Iron Co., Westmoreland, N. Y.
Westmoreland Plastics Co., Inc., 135 Gertrude St., Latrobe, Pa.
Wheeling Steel Corp., 1134-40 Market St., Wheeling, W. Va.
White Metal Rolling & Stamping Corp., 80 Moultrie St., Brooklyn 22, N. Y.

Bold face indicates supplier advertises in this issue

White Pine Copper Co., 24 Federal St., Boston 10, Mass.
White Sewing Machine Corp., Apex Reinforced Plastics Div., Elm & Washington, Cleveland 13, Ohio
Whitehead Metal Products Co., Inc., 303 W 10th St., New York 14, N. Y. (Ad pp 141, 142)
Whyte, Oliver Co., Inc., 169 Mystic Ave., Medford 55, Mass.
Whyte Mfg. Co., Inc., 115 4th Ave., New York 3, N. Y.
Wicks Corp., U.S. Graphite Co. Div., 1621 Holland Ave., Saginaw, Mich.
Wickwire Bros., Inc., 189 Main St., Cortland, N. Y.
Wilcox Forging Corp., E Allen St., Mechanicsburg, Pa.
Wildberg Bros. Smelting & Refining Co., 742 Market St., San Francisco 2, Calif.
Wilde Drop Forge & Tool Co., Inc., 2938 Fairmount Ave., Kansas City 8, Mo.
Wilder Mfg. Co., Inc., Route 2, Box 880, Carmel, Calif.
Williamette Iron & Steel Co., 2800 NW Front Ave., Portland 10, Ore.
Williams, A. C., Co., Ravenna, Ohio
Williams, E. A. & Son, 325 Washington Ave., Carlstadt, N. J.
Williams, F. B., 507 E Pershing Rd., Chicago 15, Ill.
Williams, H. E., 106 S Main St., Carthage, Mo.
Williams, J. H. & Co., 400 Vulcan St., Buffalo 7, N. Y.
Williams Gold Refining Co., Inc., 2978 Main St., Buffalo, N. Y.
Williamson Adhesives, Inc., 8220 Kimball Ave., Skokie, Ill.
Wilmington Fibre Specialty Co., New Castle, Del.
Wilson, H. A. Co., 2665 U.S. Route 22, Union, N. J. (Ad p 320)
Wilson-Hurd Mfg. Co., Inc., Lines St., Wausau, Wis.
Winston Steel Works, 4600 W Capitol Ave., West Sacramento, Calif.
Winters Foundry & Machine Co., Inc., 4125 Mahoning Rd. NE, Canton 5, Ohio
Winworth Co., Inc., 43 Oak St., Delawanna, N. J.
Wire & Iron Products Inc., 1725 16th St., Detroit 16, Mich.
Wirth, Carl & Son, 1625 Clinton Ave. N, Rochester 17, N. Y.
Wisconsin Aluminum Foundry Co., Inc., 16th & Franklin Sts., Manitowoc, Wis.
Wisconsin Gasket & Mfg. Co., Granville, Wis.
Witt Cornice Co., 2118 Winchell Ave., Cincinnati 14, Ohio
Wittman, Lawrence & Co., 40 Brooklyn Ave., Massapequa, N. Y.
Wollaston Foundry Corp., 24 Holbrook Rd., Quincy 71, Mass.
Wolverine Porcelain Enameling Co., 3350 Scotten Ave., Detroit 10, Mich.
Wood, John & Co., 509 Front Ave., St. Paul 3, Minn.
Woodruff & Edwards, Inc., 119 N State St., Elgin, Ill.
Woolf Aircraft Products, Inc., 3441 Filbert St., Wayne, Mich.
Wooster Rubber Co., Jamestown Finishers, Inc., Sub., 125 Blackstone Ave., Jamestown, N. Y.
Worcester Pressed Steel Co., 100 Barber Ave., Worcester 6, Mass.
Worcester Stamped Metal Co., 9 Hunt St., Worcester, Mass.
World Plastex, 1685 Boone Ave., New York 60, N. Y.
Worthington Corp., 401 Worthington Ave., Harrison, N. J.
Woth Co., Briggs & Union Sts., Stevens Point, Wis.
Wrought Washer Mfg. Co., 2211 E Bay St., Milwaukee 7, Wis.
Wuest Bros., Inc., 936 W Hill St., Louisville 8, Ky.
Wyatt Metal & Boiler Works, 6200 Kansas, Houston, Tex.
Wycoff Steel Co., P. O. Box 1256, Pittsburgh 30, Pa.
Wyman-Gordon Co., 105 Madison St., Worcester 1, Mass.

X

X-Pando Corp., 43-15 36th St., Long Island City 1, N. Y.
Xylos Rubber Co., 1300 Emerling Ave., Akron, Ohio

Y

Yale & Towne Mfg. Co., Powdered Metal Products Div., 9335 W Belmont Ave., Franklin Park, Ill (Ad p 336)
Yardley Plastics Co., 142 Parsons Ave., Columbus, Ohio
York Castings, Inc., 32 Latta Rd., Rochester 12, N. Y.
Youngstown Mfg., Inc., 66-76 S Prospect St., Youngstown, Ohio
Youngstown Sheet & Tube Co., Stambaugh Bldg., Youngstown 1, Ohio

Z

Z & H Mfg. Co., 31 Welcher Ave., Peekskill, N. Y.
Zellner Corp., Fort Wayne Rd., Defiance, Ohio
Zellner Foundry Co., 2088 Scranton Rd., Cleveland 13, Ohio
Zenith Foundry Co, 1501 S 83rd St., Milwaukee 14, Wis. (Ad p 359)
Zenith Plastics Co., 1600 W 135th St., Gardena, Calif.
Zenith Plastics Co., 3901 Superior Ave., Cleveland, Ohio
Zophar Mills Inc., 112-130 26th St., Brooklyn, N. Y.